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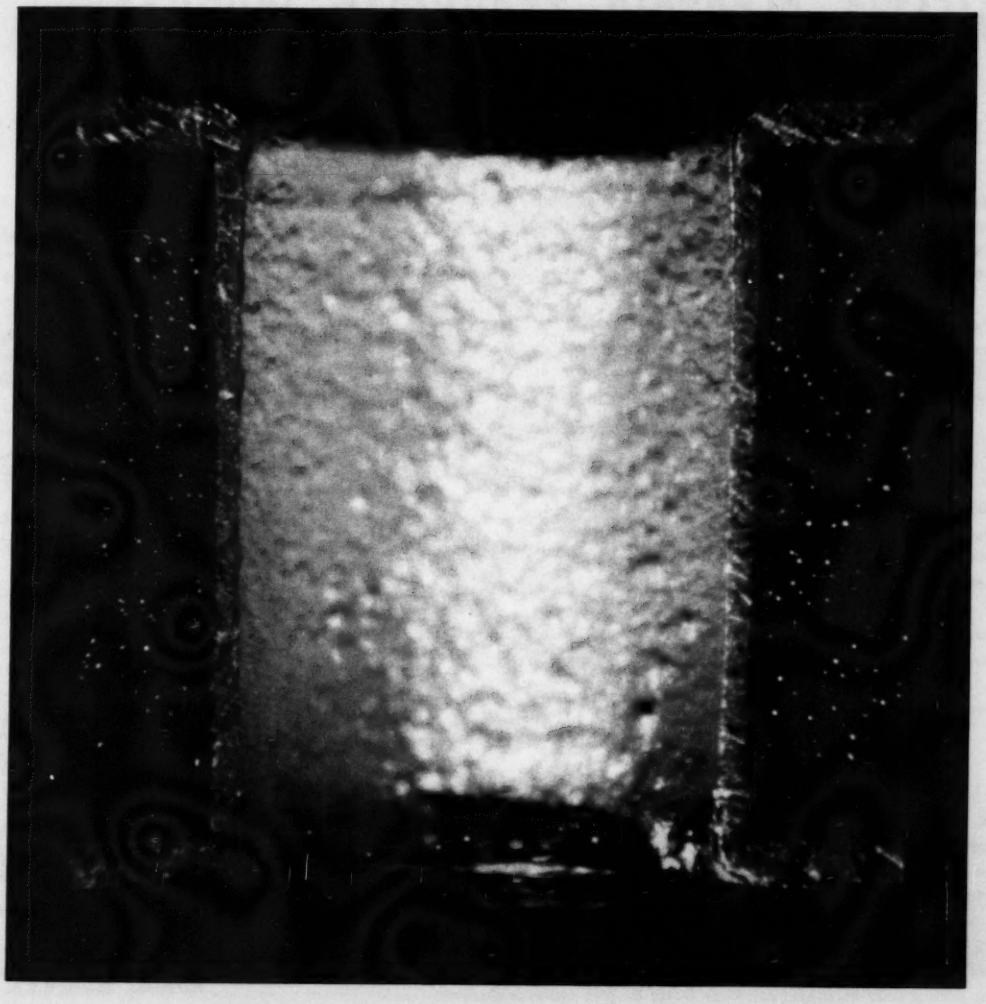
AUTOMATIC ELECTRIC

TECHNICAL JOURNAL



JANUARY, 1961 VOL. 7, NO. 5

GENERAL SYSTEM

JANUARY, 1961 VOL. 7, NO. 5

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AUTOMATIC ELECTRIC TECHNICAL JOURNAL

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Apto para grabar mensajes salientes hasta de tres minutos de duración y mensajes entrantes hasta por un total de dos horas. Cuenta también con un dispositivo accionado con el pie para regular la velocidad del mecanismo para volver a escuchar los mensajes.

WALTER AXELSEN
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Algunos de los nuevos relevadores y modificaciones de los del "tipo teléfono" que están siendo diseñados por ingenieros de la AE para hacer frente a los problemas encontrados en el ramo industrial y militar de la época moderna.

HIGH-QUALITY PRINTED WIRING
For Telephone Equipment

By R. O. Stoehr
Automatic Electric Laboratories, Inc.

Whenever the design of equipment employing electronic-type components is undertaken, printed wiring can no longer be overlooked. Since the days of World War II, when printed wiring was introduced as part of a proximity fuse development, this technique has been used in and for countless devices, including radios, television sets, missiles, wiring harnesses, motor armatures, switch banks, and computers. Although initially used primarily in radio, television, and military electronics, printed wiring is rapidly finding its way into the appliance and automobile industry. And as electronic components are increasingly used in telephone equipment, telephone men will find it desirable to familiarize themselves with printed wiring and its advantages, and with the proper techniques for maintaining equipment units mounted on printed-circuit boards.

Although the earliest type of printed wiring was made by actually printing in conducting inks on sheets of plastic, the term as used in this article refers to a process which uses "laminates"—sheets of insulating material to which copper has been laminated on one or both sides. The "printed" wiring is made by etching the copper away, except in the areas which make up the circuit conductors.

There are other ways by which printed wiring boards can be produced. They can be made by a stamping transfer method, by plating entirely on a chemically-reduced metallic film, by molding, or by a combination of these, and by other processes. One interesting technique, though not truly "printed" wiring, is that developed by Lenkurt Electric Co.; here a series of wire staples of various span lengths are stitched into the base material, and the components are attached to them. The staples serve as conductors interconnecting the components.

The processing techniques used at Automatic Electric, however, are generally referred to as "copper-subtractive" and involve the use of copper-clad laminates as described above. This process offers the most versatility and is the most readily adaptable to changes in printed wiring design techniques. In Automatic Electric's new Printed Wiring Department (Figure 1) this "copper-subtractive" process is carried out under carefully controlled production conditions. This article outlines the many considerations involved in the design and production of printed wiring boards that will be capable of meeting the exacting requirements of use in high-quality telephone equipment.

Equipment Mounting and Connections

Components are mounted in a number of ways on these boards. Small, axial-lead components, such as resistors, are usually mounted by soldering their leads to the wiring—the leads serving as both connection and support for the unit. Larger, or heavier, components may be mounted by their terminals also, but are usually supported by additional mounting screws or rivets. The lead holes are located so as to pass through the wiring pattern at the proper points, and the wiring in the area around each hole (called "land area") is enlarged to permit a sound, reliable, solder joint.

Connections between the equipment and the wiring on the other side of the board are made

by "dip soldering"— passing the board through the molten solder so that the bottom only is immersed. For transistors, tubes, or diodes that might require even occasional replacement, sockets or mounting studs are provided.

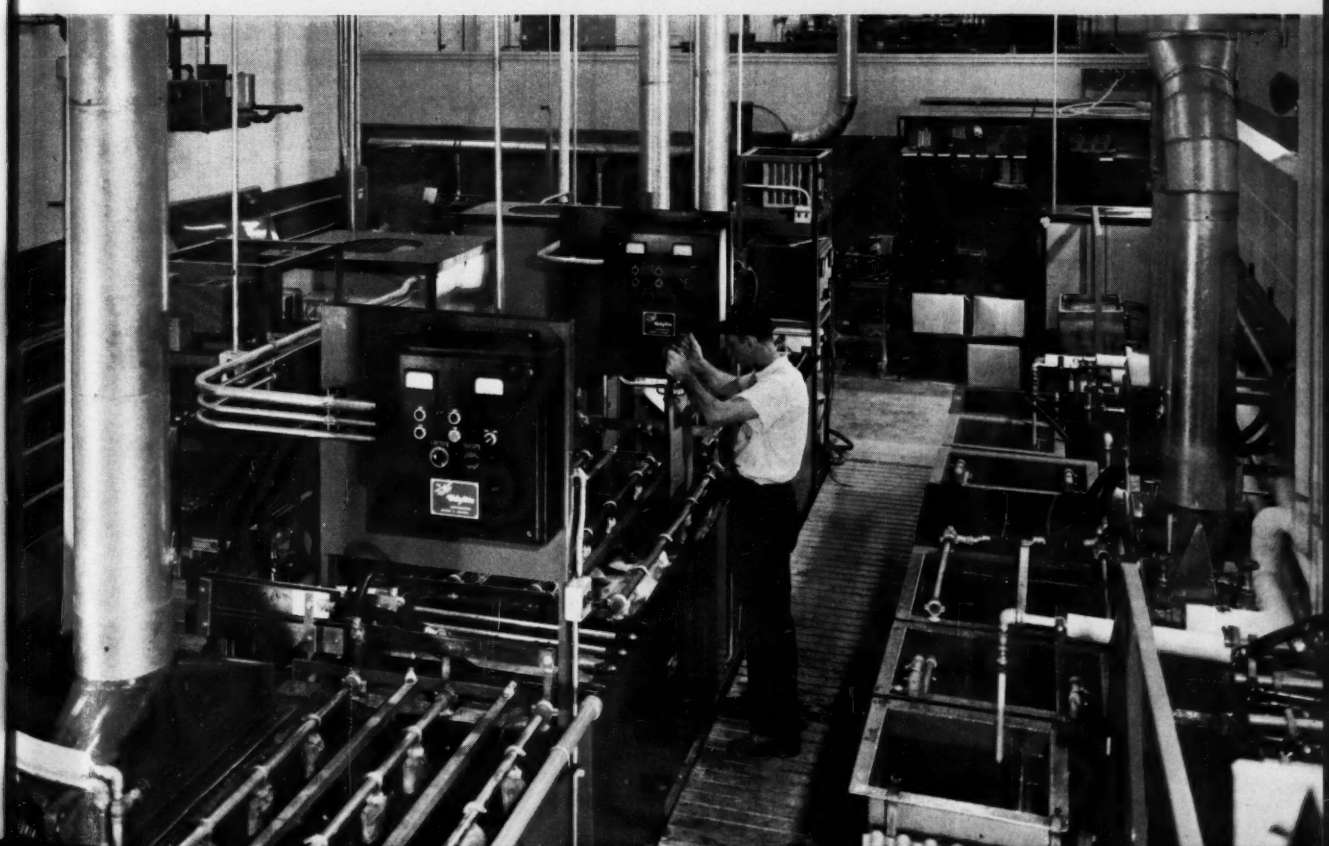
Where laminates with printed wiring on both sides are used, it is usually necessary to complete connections between the two sides of the board at various points. This may be done by inserting eyelets through the board, but it is better to use plated-through holes, as shown on the front cover of this issue; this assures interface connections of permanently low resistance.

Connections to the external equipment are almost invariably made through connecting contacts at the edge of the board; this permits easy removal and replacement of the printed wiring board in its mounting.

The reasons for using printed wiring may vary from application to application, but generally reflect a desire for either cost saving or miniaturized assembly. In its infancy, printed wiring was often misused; in most cases the misuse resulted from attempting to directly adapt this technique to conventional design, rather than designing the equipment for printed wiring. A good example of this is the television receivers of a few years ago, in which ruptured wiring patterns and intermittent solder joints were the serviceman's nightmare. Experience and education on the part of the set designer, combined with improved laminated materials and board manufacturing techniques, have helped to overcome these early difficulties.

At Automatic Electric Laboratories, Inc., a rigid set of standards has been established, to assure that all aspects of printed-wiring-board design are given adequate consideration, and that all boards are based on the best design principles.

Figure 1. Over-all view of printed-wiring board plating and etching room, showing plater in process of removing plated sheet from nickel bath. The preliminary cleaning cycle (right foreground) includes acid dips. For the plating cycle, the plater starts in the left foreground and proceeds to the rear—following this with final cleaning and etching operations shown on the extreme left.



Advantages of Printed Wiring

From the manufacturer's point of view there are a number of advantages to printed wiring:

(1) It saves much of the drafting time and reproduction of the volume of blueprints needed to plan a conventional electronic assembly.

(2) There is a saving in production costs, most readily realized as volume increases, and as automated assembly and soldering techniques are employed in manufacture.

(3) There is a saving in space required for the assembly. Printed wiring permits much of the "air" to be designed out of a piece of equipment. This makes possible such compact devices as the Type 88T Speakerphone, and Automatic's new AT-6 repeater.*

(4) It is possible to reduce detailed inspection routines, and where volume warrants, it makes possible completely automatic inspection and component routining techniques (Figure 2).

These are vital reasons and must be considered in today's highly competitive markets. But what about the user of devices employing printed wiring — in what way does he benefit? In most cases the operating company is not concerned with how the item is constructed or designed, so long as its operation is satisfactory and trouble-free.

These advantages of printed wiring to the user are, however, clearly evident:

(1) Printed wiring assures complete interchangeability of like subunits. By means of a connector, one assembly is quickly removed and a new one inserted in its place.

(2) Instant removal and replacement of units can mean that less time is required for a service call by the repairman.

(3) Printed wiring facilitates testing and fault-finding. The wiring is plainly laid out where it can be readily traced. Furthermore, because the assemblies can be removed, it is possible to repair them at the bench, where suitable testing facilities and tools are available.

(4) The use of printed wiring in central-office equipment makes better use of rack space and, as it is generally more compact, such equipment usually requires less floor space than conventional equipment.

*New Negative-impedance Repeater Permits Accurate Impedance Matching, R. P. Dimmer, Automatic Electric Technical Journal, April, 1960.

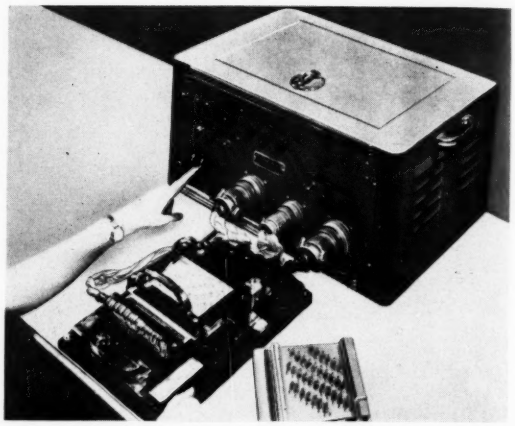


Figure 2. Semiautomated testing and routining equipment for board assemblies.

It can be seen that much is to be gained, by both manufacturer and user, from the use of printed wiring. The technique is now firmly established and will continue to find its way into more and more electronic and semielectronic devices. It is estimated that during 1960, more than 20 million square feet of copper-clad laminate will be produced.

Now, let us examine printed wiring — what it is, how boards are designed and made, and how printed wiring assemblies are used.

Design and Layout

Before it is decided that printed wiring should be used for a proposed piece of electronic equipment, it must first be determined:

(1) Whether the quantity of assemblies will be sufficient to provide the cost advantages of printed wiring. However, in spite of its higher cost, printed wiring can often be justified, or may even be a virtual necessity, where space is at a premium in the final assembly.

(2) Whether a two-dimensional layout of equipment is feasible — which is usually the case when electronic-type components are used. It might be decided that larger transformers, relays, or power transistors should be kept off the printed-wiring board. The logical division of components

and the number of interconnections must be carefully considered.

(3) Whether the wiring pattern or circuit to be reproduced on the board is subject to change as a result of specific customer requirements. If changes occur frequently (or strapping is required for other reasons), suitable strapping terminals should be provided on the component side of the board.

In most cases the physical shape of the printed board will be determined by various associated factors. It may be necessary for the board to conform to a particular established housing; the board width may be determined by the width of a relay mounting strip, or by the number of external connections required; slots and cutouts may often be necessary to permit the board to fit around other apparatus.

In many cases, in designing the board to fit into existing telephone equipment, all three dimensions of the board are rigidly determined by the housing, and the designer has little leeway in layout of his circuitry. In somewhat more rare, but ideal cases, the apparatus is designed around the board, and the designer's problems are greatly simplified in this way.

The first step in actual design is usually the making of a cardboard mock-up to establish a rough layout of the components. The wiring pattern is traced in pencil on the dip-solder side, and the components rearranged, if necessary, to minimize wiring crossovers. In most cases where the board size has not been previously fixed, it will be a function of the component density. When this approach would result in extreme wiring density, or when numerous crossovers would otherwise be unavoidable, a double-sided board may be considered.

Once the mock-up meets the designer's requirements, one or a number of etched wiring boards are produced by one of several "quickie" processes. In this manner, the designer can obtain one, or more, functional boards for his initial working model at relatively little expense. The wiring pattern may actually be reproduced in acid-resistant tape, directly on a piece of copper-clad laminate, and then etched; or, the pattern may be cut on a Mylar-backed strip-emulsion film which can be transferred directly to a silk screen, for silk-screen printing, using acid-resistant inks. This printing method makes possible the reproduction of considerable number of printed-wiring boards, if needed for test.

When these boards have been judged satisfactory, the master drawing is begun; it will show all wiring to an expanded scale — usually 2 or 4 to 1. The layout is based on a one-tenth-inch grid, all component holes being spotted at the intersections of the grid lines.

After all components have been located, the necessary land areas, connector tabs, and interconnecting conductor patterns are then reproduced. There are several established methods of doing this. Ink was initially the most widespread means, but now nonreflective tapes in various conductor widths and land area sizes are available, and have been used in an increasing number of applications. One method that looks very promising, and is being tried experimentally at Automatic Electric Laboratories, Inc., is the use of a red "cut-and-peel" film for location of land areas, and red nonreflective tape for conductors. This combination offers both speed and accuracy in producing a master.

From these masters, photographically-reduced negatives and positives are produced, which are then used to produce silk screens (Figure 3) — which, in turn, are used for the actual printed wiring board production.

Figure 3. Technician inspecting silk-screen for absence of flaws and accuracy of reproduction.

Table 1. Typical properties of some copper-clad laminates.

PROPERTIES	PAPER-PHENOLIC (XXXP)	EPOXY-PAPER	EPOXY-GLASS (G-10)
Flexural Strength (Lengthwise)—psi	12,000	18,000	55,000
Water Absorption (1/16", 24 hrs.) %	1.0	0.5	0.35
Copper Bond Strength (1" width, 1 oz. copper) —lb./in.	6-8	8-10	8-10
Blister Resistance (1" Squares)	260° C for 5 sec.	260° C for 5 sec.	288° C for 5 sec.
Volume Resistivity —Megohm—cm	$10x10^6$	$2x10^6$	$20x10^6$
Dissipation Factor (1 mc)	.035	.030	.020
Dielectric Const. (1 mc)	4.6	4.0	4.3
Maximum Operating Temp. (°C)	120	120	160

Board Materials

One of the most important factors to be considered in producing a printed-wiring board is the type of base material to be used. The most common is an electrical grade of paper-based material impregnated with a phenolic resin (NEMA grade XXXP). This laminate is the "work-horse" of the industry and, under average environmental and mechanical conditions, is highly satisfactory, having both good electrical and mechanical properties. For more severe conditions, involving extremes in thermal shock, vibration, or moisture, a glass-fiber reinforced plastic laminate impregnated with an epoxy resin is desirable. This material (NEMA grade G-10 and G-11) is also recommended when the board becomes unusually large (say, larger than 40 square inches), or when the components to be mounted are heavy and bulky.

Epoxy-paper laminates are not yet generally used since they are relatively new but they have some of the advantages of both epoxy-glass and phenolic-paper. There are other base materials which serve more specialized functions, such as flame-retardance or resistance to arcing across the surface. Still others are available when exceptional electrical or mechanical properties are required. However, these materials also have some drawbacks, of which initial cost is not always the least to be considered.

Laminates are available with various thicknesses of copper on one or both sides — from ½ ounce to 5 ounces per square foot of copper sheet; a sheet of 1-ounce copper is .00135" thick. A 1/16" wide conductor of this sheet thickness can carry about 4 amperes without exceeding a maximum temperature rise of 40°C, and without impairing the bond between the copper and the base material. This means that although this conductor has a cross-sectional area only slightly larger than a No. 31 AWG wire, it has the current-carrying capacity of No. 18 AWG plastic-insulated wire!

One of the most important phases of board fabrication is the inspection of the copper-clad laminate when it is received. This has been the subject of much concern by both material suppliers and board fabricators. A comprehensive inspection will evaluate the electrical, mechanical, and physical properties of a material, and is usually based on a test pattern which is processed in the same manner as the boards.

A circular test pattern is used to make volume and surface resistivity measurements, while a series of parallel-etched conductors are used to determine the bond strength of the copper to the base laminate. A pattern of four copper squares is a means of evaluating the resistance of a particular laminate to blistering as a result of direct solder immersion.

Other tests are used to determine the flexure and tensile strengths of the material, as well as its rate of moisture absorption and heat resistance. Table I shows typical properties of phenolic-paper, epoxy-paper, and epoxy-glass laminates.

Finishing

For the highest quality wiring boards, some type of finish is usually required over the copper wiring pattern. Inexpensive boards, or boards that are used in such quantities as not to require long shelf-life protection, are often given no protective coating. Usually, a chemical or mechanical cleaning operation to remove any oxide, and fluxing just prior to assembly, suffice for these boards. Some fabricators employ a water-dip lacquer which is of questionable value.

In cases where connecting contacts are part of the board, or where plated-through holes are required, solder plating, or a combination of copper, nickel, and gold plating are generally used. The latter is by far the most expensive, but also offers the best corrosion protection, is an excellent soldering aid, and provides good, low-resistance con-

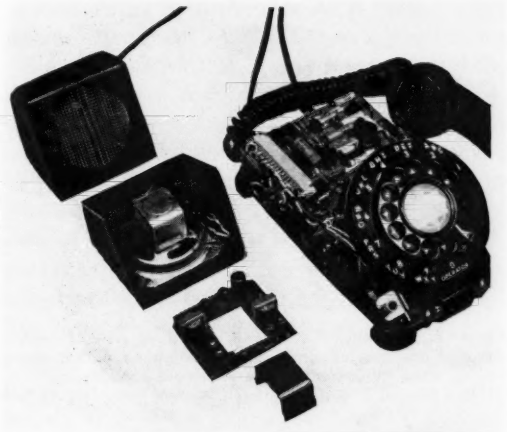


Figure 4. Disassembled view of the compact 88T Speakerphone, showing the amplifier board assembly mounted inside the telephone and the speaker board assembly with its mounting clip alongside.

tact at the tabs. Solder plating is coming more into its own as studies of connectors indicate that solder-plated contact tabs have relatively more merit than originally thought. Special electroplatings, such as rhodium, are often used when good conductivity and exceptional wear resistance are required.

Metallic protective coatings, applied by means other than electroplating, are also sometimes used. One company has devised a means of roller-coating boards with solder, which for single-sided work is said to be less expensive than solder plating. Electroless, or dip-type, gold solutions are also used for short-term conductor protection and as an aid to soldering.

Some factors of rather intangible value must also be considered in finalizing a board design for production. Will assembly, or servicing, be simplified if the component holes are designated by screened letters, or numbers, on the component side of the board? Should the wiring pattern be repeated in ink on the component side to facilitate circuit trouble shooting? (In either of these cases, master drawings are made of the necessary designations or wiring.) Is the board of sufficient size, or the wiring so dense, that a solder mask, which will limit soldering to land areas only, should be considered? No generalizations can be made—these factors must be considered on the basis of designer preference and actual experience in the field.

Board Fabrication

The production of a printed wiring board begins with the cutting of the laminate into sheet sizes that can be conveniently handled throughout the processing. Pilot holes, if required for positioning of subsequent operations, are punched or drilled at this time. If the board is to be double-sided with plated-through holes, component holes are drilled also, and burrs and drilling chips are removed. Copper is then chemically deposited in the holes. The sheets are thoroughly cleaned (usually both mechanically and chemically) and are otherwise prepared for the silk-screen printing operation.

The wiring pattern is reproduced as such, or as its negative, in an acid-resistant ink on the laminate. In the former case, the board goes directly into the etchant which removes all copper but that of the wiring pattern.

In the latter case, the board is electroplated; copper, nickel, and gold, or nickel and rhodium, or solder, are deposited to form the wiring pattern. When plated-through holes are required on double-sided boards the plating produces a series of continuous conductive tubelets from one side to the other. After plating, the acid-resistant ink is removed, and the board is placed in a suitable "selective" etchant, which removes the bare copper but does not affect the plated surfaces. The board is rinsed, fabricated, and cleaned. Lettering and solder masks, as may be required, are screened on the board. Then a final inspection completes the processing.

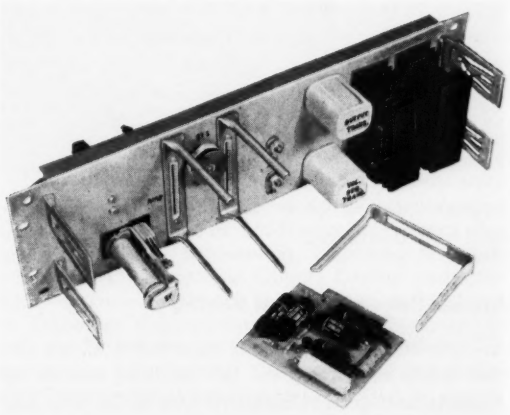


Figure 5. Showing board guides used to mount individual board assemblies on relay mounting plates.

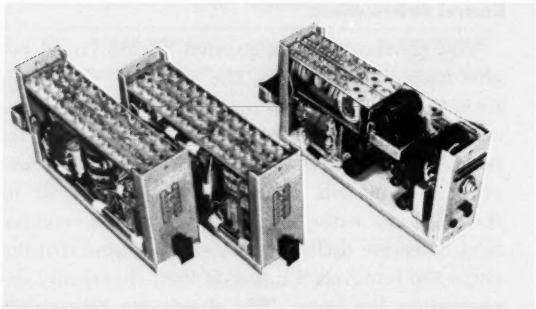


Figure 6. Comparison of present AT-2 and AT-3 Repeaters with new AT-6 Negative Impedance Repeater, revealing the space saving accomplished by use of printed wiring.

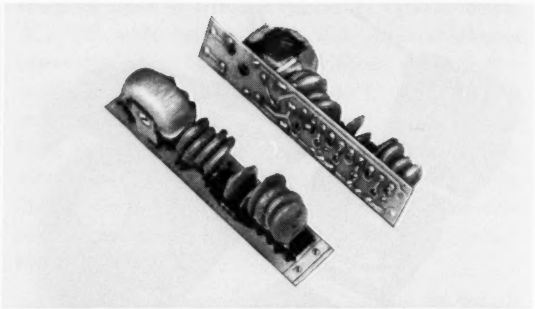


Figure 7. Compensating network board of AT-6 Repeater, showing mounting of toroid and capacitors on printed board having screw adjustment to add or remove capacitance.

Assembly and Soldering

One of the advantages of using printed wiring is that automated assembly and mass soldering of components is possible. However, in the telephone industry, printed boards are often used to permit compact instrument design, even though only a limited quantity of boards is required. Here, completely automated assembly is difficult to justify. Most components are hand-inserted, and machines are used primarily for lead-forming and lead-cutting operations. Lugs, studs, terminals, and eyelets are inserted by eyeletting machines, either singly, or in group patterns. Sensitive components such as transistors and diodes are usually mounted with either long leads, or heat sinks, to prevent heat damage to them during soldering.

After the components have been mounted, contact tab areas and other areas not to receive solder are masked with tape, and the solder surface of the board is prepared with flux. Soldering is accomplished by passing the board through a solder pot for a relatively short period of time, allowing the solder to sweat the component leads to their associated land areas on the board. Subsequent cleaning operations consist of flux removal and sometimes immersion cleaning in a soap or detergent solution when surface leakages must be held at a minimum.

Applications of Printed Wiring

New applications employing printed wiring are constantly appearing on the drafting boards at Automatic Electric Company. One of the first was the Type 88T Speakerphone (Figure 4). This employs two small boards—one in the telephone housing proper and the other in the speaker cabinet. Paper-phenolic laminate was selected for this application. Both boards are 1/16″ thick, with one-ounce copper on both sides, and have plated-through holes. The physical design of the speaker board is such as to permit it to be mounted by means of a spring clip onto the speaker magnet. Because of printed wiring this telephone unit is self-contained and requires no cumbersome additional equipment. Incidentally, this is an excellent example of the physical dimensions of the board having been determined by the equipment housings.

Another application of printed wiring occurs in the Type 59 SATT Detector.* The use of printed wiring made it possible to dispense with lamp sockets, and much otherwise tedious hand wiring is now being reproduced photochemically. The installation of this detector at Lincoln, Neb., represents the largest single installation employing printed wiring thus far made by Automatic Electric; a total of just under 1,900 board assemblies were required.

Figure 5 shows a convenient method of mounting individual printed-wiring boards on relay mounting strips, without requiring an elaborate rack design to hold these boards. An inexpensive board-guide is formed from sheet metal and is perforated to accept the board connector. The tooling for this guide is of flexible design, to permit production of guides for various widths of boards and for various sizes of connectors.

One of the most rewarding applications of

*New, Versatile Detector for Type 59 SATT Systems, R. O. Stoehr and B. Sherstiuk, Automatic Electric Technical Journal, July, 1959.

printed wiring is in the new AT-6 Negative-Impedance Repeater* (Figure 6). As a result of the redesign of the AT-2 and AT-3 Repeaters and the use of electronic components and printed wiring, the functions of these two repeaters (the two units on the left) are now performed by a single unit (the AT-6, on the right). Figure 7 shows in detail two views of the compensating network used in the AT-6, illustrating the compact assembly of a toroid and numerous capacitors. The actual size of this board is only 1 inch by 4 inches! The material is 1/16" epoxy-paper.

Other examples of applications of printed wiring boards are the Multi-frequency Pulsing Unit† and the Waystation Dialing System‡. A developmental model of a 100-Line Electronic Private Automatic Telephone Switchboard** illustrates that engineers at the Laboratories, who are thinking of the future, are thinking printed wiring.

Maintenance of Printed-wiring Boards

When the art was in its infancy and commercial promoters looked to printed wiring as a "cheap and dirty" method of circumventing rising labor costs, field servicing of board assemblies presented numerous headaches. With improvements in materials, and an accumulation of service experience by repairmen, these problems have been greatly reduced; even so, some basic servicing hints should be kept in mind.

First, do not attack a printed-wiring board directly with a high-wattage iron. (You certainly wouldn't use a blow-torch to solder a terminal block!) A low-wattage, pencil-type iron is best, but if this is not available, a large iron may be adapted by wrapping its tip with a heavy copper wire to serve as a secondary tip.

Second, do not dwell on the land areas longer than necessary to remove a component lead. Better yet, clip the leads of the faulty component close to its body, and solder the new component to the old leads protruding from the board.

Breaks in copper foil conductors, if they are of the hairline type, can be repaired by flowing solder over them. Larger breaks can be joined by means of a bare wire strap.

Remember, a little caution goes a long way in performing successful repairs on printed-wiring boards. Repairs should generally be few, provided the boards are properly handled—as any piece of electronic apparatus should be!

Summary

Future designs in telephone equipment will reflect more than ever the benefits secured by the use of printed wiring. This technique will find its way more and more into central office as well as subscribers' equipment. It offers advantages of compactness combined with ruggedness, which cannot practically be secured in other ways.

Rudolph O. Stoehr, graduate of Northwestern University in 1950, has a Bachelor of Science degree in Electrical Engineering. Beginning his work with Automatic Electric in Quality Control and later entering Training School, he has held assignments in Exchange Engineering, Apparatus Engineering, and the Testing Bureau. Mr. Stoehr is Supervisor of the Process Development Group of the Product Design Department of Laboratories, working on equipment and process developments, the latest of which has been the design of the printed-wiring-board plating and etching facilities.

*New Negative-impedance Repeater Permits Accurate Impedance Matching, R. P. Dimmer, Automatic Electric Technical Journal, April, 1960.

†A New Multi-frequency Pulsing Unit for Inter-office Trunk Signaling, R. P. Sanders, Automatic Electric Technical Journal, February, 1960.

‡Waystation Dialing System Provides Dial Service on Message Lines, R. P. Dimmer and E. L. Roback, Automatic Electric Technical Journal, July, 1960.

**A 100-line Electronic Private Automatic Telephone Switchboard, J. G. Van Bosse, Automatic Electric Technical Journal, April, 1960.

THE MODEL LP ELECTRONIC SECRETARY*

Telephone Answering Set

By E. A. Marheine
Electronic Secretary Industries, Inc.

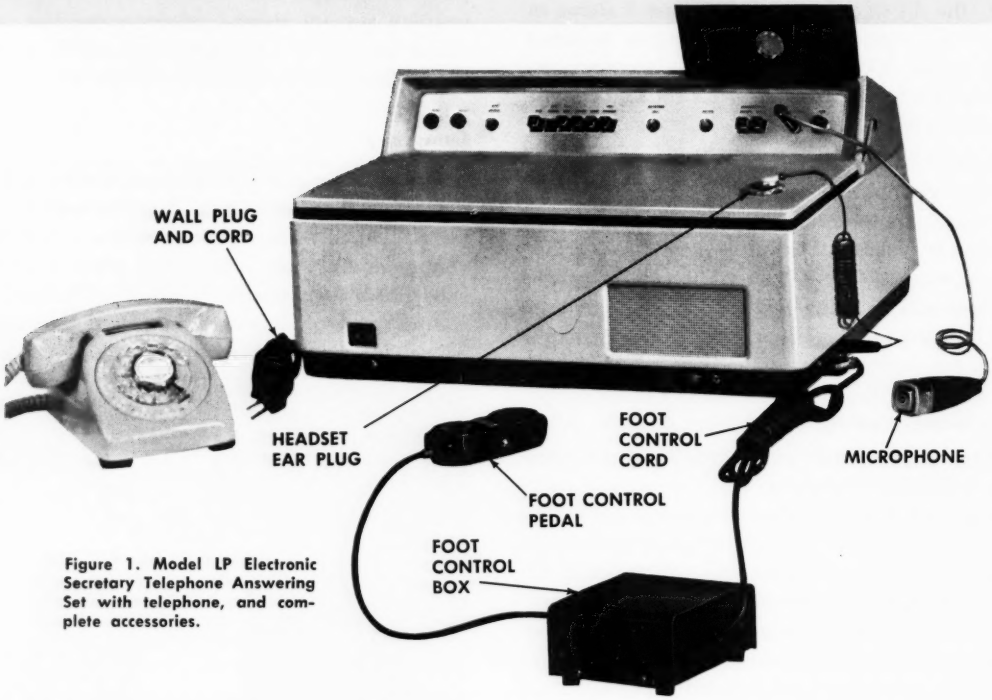


Figure 1. Model LP Electronic Secretary Telephone Answering Set with telephone, and complete accessories.

To bring to public attention the fact that we were introducing a totally modern contribution to the field of telephone answering, Raymond Loewy, internationally famous industrial designer, has helped us design a cabinet for our new long-playing (Model LP) Electronic Secretary Telephone Answering Set (Figure 1). His cabinet design matches the spirit of the requirements we set for ourselves in planning this machine.

For easy servicing, the equipment is sectionalized as shown in Figure 2:

1. The cabinet, or "wrapper", including a bottom pan.
2. The transport mechanism, including the tape deck, motor board, motor control, and speaker.
3. The chassis, including power supply, basic switching equipment, and three plug-in printed-wiring boards.

For recording the outgoing announcement, a small hand-microphone is provided. Other accessories, available optionally, include an ear-plug headset, and a foot control. The headset is used when privacy is desired in playing back the outgoing announcement or incoming messages (which are otherwise heard through the loud speaker). The foot control is used for transcription of messages; it enables the transcriber to start, stop, rewind, and backspace the playback mechanism while keeping the hands free for writing or typing.

Electronic Secretary is a registered trade-mark of Electronic Secretary Industries, Inc.

Design Requirements

Conferences established that the new design had to meet the following requirements:

1. It was to be completely transistorized.

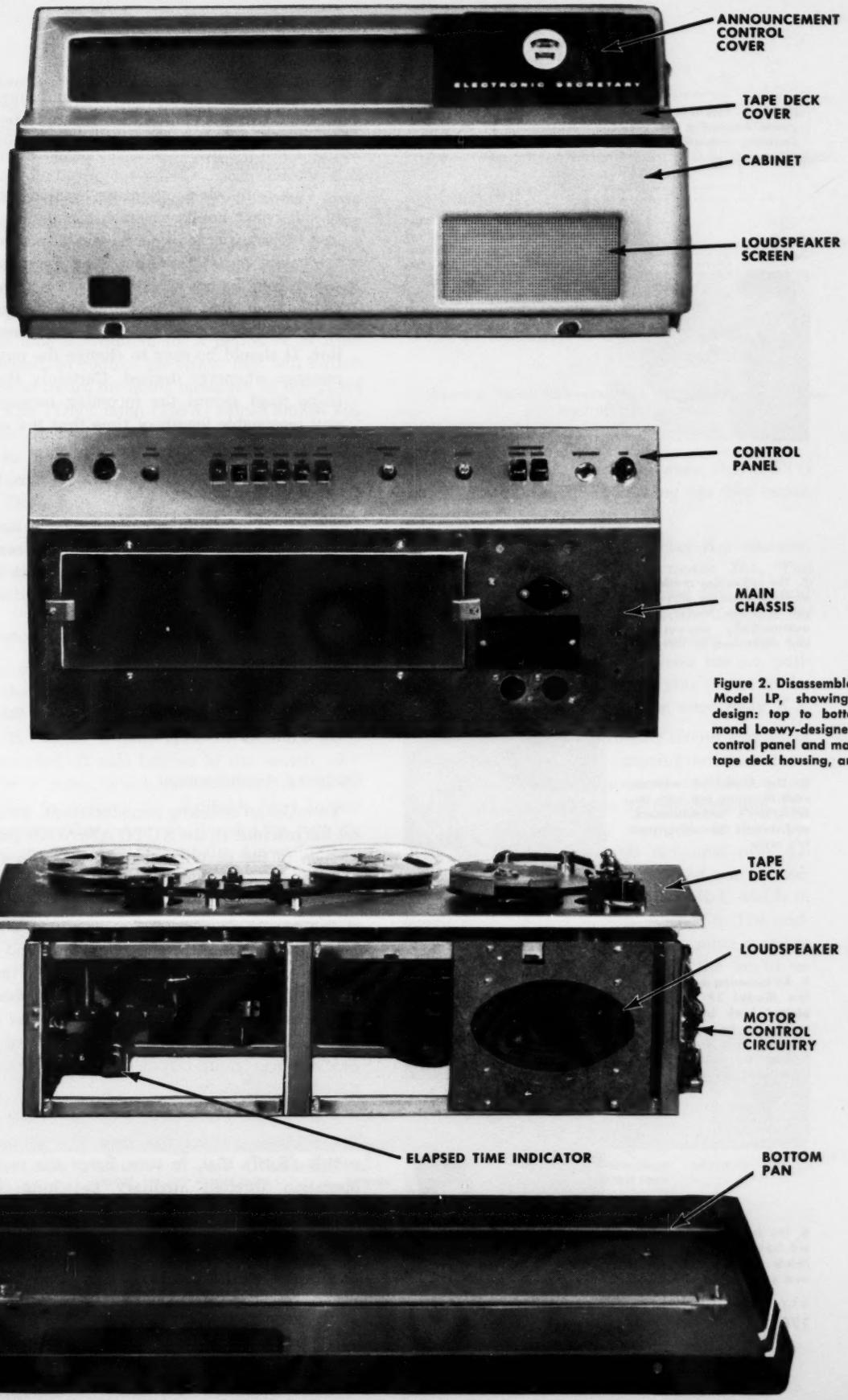
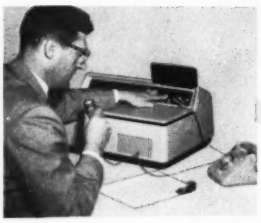


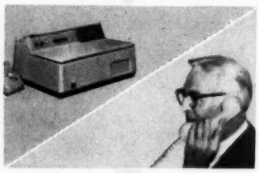
Figure 2. Disassembled view of Model LP, showing sectional design: top to bottom — Raymond Loewy-designed cabinet, control panel and main chassis, tape deck housing, and bottom.

Figure 3. Functions of model LP Electronic Secretary Telephone Answering Set. Previous models made by Electronic Secretary Industries have established that an answering set should perform these functions for the subscriber:



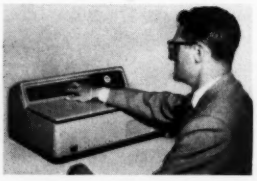
1. The subscriber records and clocks his announcement, making sure his announcement will not run over three minutes—e.g., "I will return to the office shortly. This machine will record your message."

2. The subscriber checks his announcement by play-back and sets the Model LP to automatically answer for him night and/or day.



3. The Model LP answers each incoming call with the subscriber's announcement, and records the calling party's reply.

4. All incoming messages on the Model LP tape are played back by the subscriber; or by using Model LP accessories, may be transcribed by his staff for permanent record.



5. The subscriber erases all old incoming messages and resets the Model LP for a new cycle.

2. Its outgoing announcement and incoming message transport mechanisms were to be completely electrically controlled. This would reduce mechanical wear.

3. This unit, when operating, was to conform to subscriber habits as much as possible. Just as a caller expects an occasional response from the called party, the Answering Set must reassure him, whenever he pauses for an appreciable time, that he is still connected to the machine and is not talking to a disconnected line. It should be easy to change the outgoing message whenever desired. Certainly the mechine must record the incoming message for any reasonable length of time that the calling party might talk.

Operating Sequence

All told, we felt these components in our sectionalized construction would best perform the five basic operating functions of this unit as depicted in Figure 3:

1. Record the announcement.
2. Check the announcement.
3. Record the incoming message.
4. Play back the incoming message.
5. Erase all messages and set the machine up for a new cycle of operation.

Outgoing Announcement

To make an outgoing announcement, we would set the machine in the AUTO ANSWER position as seen in the partial schematic (Figure 4), by depressing the AUTO ANSWER button (Figure 5), lifting the black cover on the right side of the panel, plugging the microphone into the MICROPHONE jack, and depressing and holding the ANNOUNCEMENT DICTATE (green) button, S-7, which connects the microphone to the record preamplifier. This button also starts the announcement tape motor (B-1), and operates a relay (K-10). This, in turn, prepares the set for recording.

The announcement tape motor thereupon drives the capstan, pulling the tape through a tape switch (S-10) that, in turn, keeps the motor in operation through auxiliary switching. Relay K-10 completes circuits to the power supply and the printed circuit amplifiers, connects the record heads and the DICTATE lamp. It also breaks the circuit to the telephone line to prevent the

machine from answering a call while a message is being recorded.

With the lighting of the DICTATE lamp, the subscriber begins his announcement; when he has finished dictating he releases push button S-7. Auxiliary dictating contacts (not shown) keep the announcement tape motor (B-1) running when S-7 is released. Automatically, with the release of push button S-7, the tone oscillator is connected to the amplifier circuit and a 1,400-cycle tone is recorded on the tape.

This tone is required, for a period of at least one second, to control the relays that will switch the Set to record incoming messages, as described later. The TONE lamp (DS-4) blinks almost 2½ seconds after the tone has been impressed on the tape, to indicate to the subscriber that the message has been satisfactorily recorded. If TONE lamp DS-4 fails to light, the subscriber knows that his announcement was too long, and did not provide time for the tone signal; the announcement must then be shortened and redictated (this automatically erases the preceding message).

Announcement Check

After playing his announcement on the tape, the subscriber may depress the ANNOUNCEMENT CHECK button. This starts announcement tape motor B-1 again, to play back the announcement just recorded. It also latches in the switch, and operates a relay, which performs the necessary switching to connect the playback head to the loudspeaker. This relay also breaks the path to the telephone line to prevent the Answering Set from answering a call while the outgoing message is being checked.

Automatic Answer Cycle

To set the machine to answer his calls, so he may work uninterruptedly, or when leaving his office, the subscriber depresses the AUTO ANSWER button. The following can then occur, as seen in Figure 6:

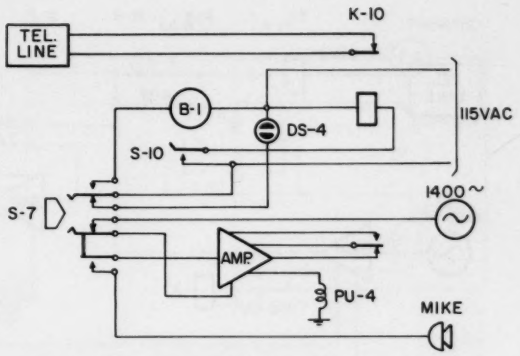


Figure 4. Partial Schematic Depicting Recording of Announcement by the Subscriber

When the telephone rings, relay K-1 operates, starting announcement tape motor B-1. The motor drives the capstan, pulling the tape and operating tape switch S-10 as before. Tape switch S-10 operates relay K-2. This latches in the announcement tape motor, completes the a.c. path to the power transformer supplying power to the amplifier, and operates the line seize relay K-3.

Relay K-3 breaks the ringing circuit and seizes the telephone line. The outgoing announcement is taken from the announcement mechanism, amplified, and delivered over the telephone line. The tone that was previously recorded on the tape, after the announcement, is delivered over the telephone line for a period of about one second. This tone operates CR latch relay K-4, which in turn operates midcycle shift relay K-5. The midcycle shift relay energizes the incoming message recorder mechanism and prepares the set to record the incoming message.

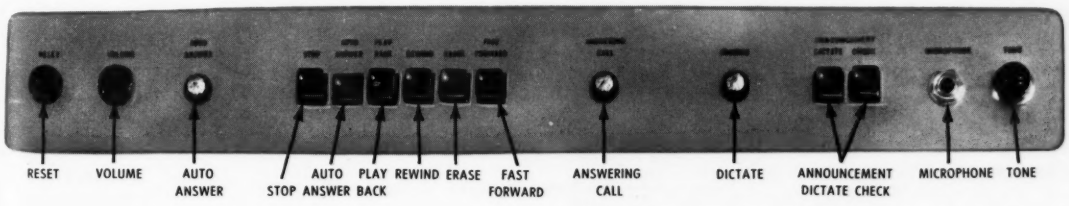


Figure 5. Control Panel on Model LP with Announcement Control Cover Raised—Shows All Buttons and Lamps

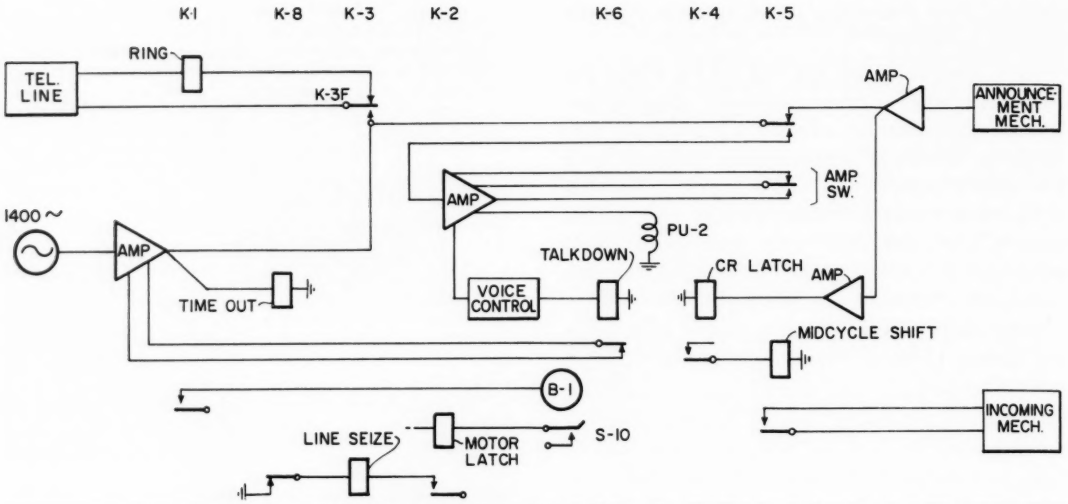


Figure 6. Partial Schematic Depicting the Automatic Answering Cycle

A portion of the incoming signal is shunted from the record amplifier to the voice control and "talk down" components. The action of the voice control is such as to keep the machine operating for the time necessary for the calling party to complete the call. If the calling party hangs up, or does not talk for a period of 12 seconds, the unit will disconnect itself from the telephone line, turn off the mechanisms, and reset itself for the next call. The optional accessory of "talk down"

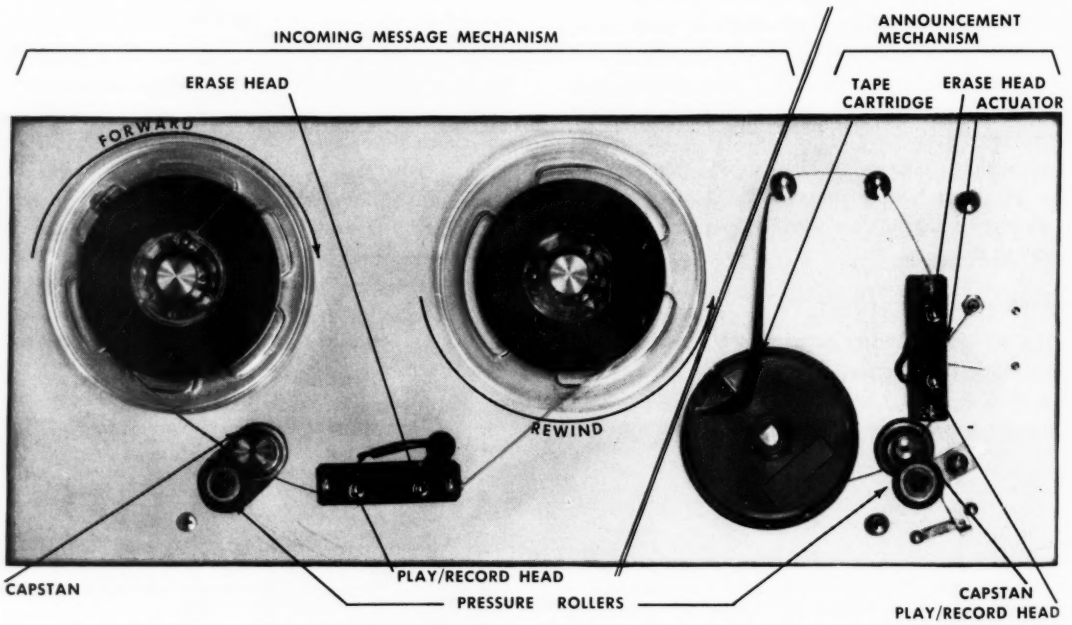


Figure 7. Tape Deck, Showing Path of Incoming Message and Announcement Tapes

provides a low warning tone after 4 seconds of silence on the part of the calling party. If the calling party then resumes talking, the tone disappears and the voice control resets itself. Otherwise, the unit disconnects itself, as just described.

Playback

Upon returning to his Electronic Secretary Telephone Answering Set, the subscriber may rewind the tape by pressing the REWIND button and may then play back any messages that were recorded in his absence. Depressing the PLAYBACK button applies power to the unit, starts the playback mechanism, and performs necessary switching for playback operation (see Figure 7). The subscriber then adjusts the VOLUME knob to his own satisfaction.

Messages are normally heard through the speaker. By wearing the headset, however, the subscriber (or a member of his staff) may eliminate office noise and assure privacy when playing back messages; inserting the headset plug into its receptacle automatically mutes the playback loudspeaker. For transcription (either through the use of the headset or from the loudspeaker), the subscriber may use a foot control.

This transfer of control enables the transcriber to start, stop, rewind, and backspace the playback mechanism with the foot control switch, leaving the hands free. The interval of backspacing is adjustable. Both the headset and foot control components are optional accessories.

Erase

To erase any messages that have been recorded, the subscriber depresses the REWIND button (which rewinds the tape onto the supply spool) and the ERASE button (which energizes the erase oscillator). The tape is thereby erased completely during the rewind operation. If the subscriber neglects to erase any messages from the tape, he need not worry about overlapping recordings; the machine will erase them during the ordinary record cycle. In this event, however, it is possible, because of pauses between new messages, to have bursts of previously-recorded messages between the new messages.

Tape Transport Mechanism

Incoming and outgoing messages are recorded on magnetic recording tape. The purpose of a tape transport is to drive the tape across the recording heads and allow the subscriber to rapidly and accurately locate any message on the tape.

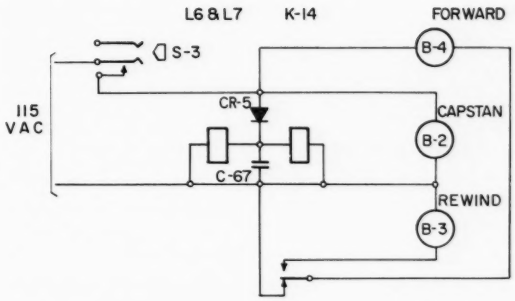


Figure 8. Partial Schematic Depicting Playback Cycle.

Our tape transport is completely electrically controlled. It employs a 3-motor transport mechanism and dynamic braking. By using dynamic brakes, all adjustment and wear problems associated with mechanical brakes are eliminated. The control mechanism consists of four relays: Play, Forward, Rewind, and Memory.

"Play" Operation

The PLAYBACK button, S-3 (Figure 8), when depressed, supplies a.c. to capstan motor B-2, and d.c. to energize the play relay, K-14, and the pressure roller magnet assembly (L6 and L7). Capacitor C-67 serves to filter the d.c. supplied by CR5, as well as to delay the release of play relay K-14. Depressing the PLAYBACK button, S-3, therefore causes the pressure roller to be pulled against the capstan by means of L6 and L7, and causes the capstan motor, B-2, to turn. This, in turn, drives the flywheel, pulling the tape across the heads from the supply (rewind) reel to the take-up (forward) reel. Relay K-14 is operated at this time, connecting forward motor B-4 and rewind motor B-3 in series. Low torque is therefore applied to the take-up and rewind motors to provide a constant back pressure of the tape on the heads. To insure long tape and head life, no pressure pads are used on this machine.

When PLAYBACK button S-3 is released, capstan motor B-2 is disconnected; however, play relay K-14 is delayed for a period of approximately

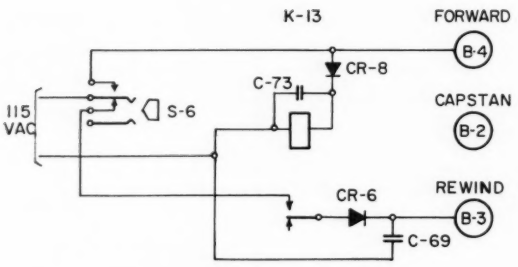


Figure 9. Partial Schematic Depicting the "Fast Forward" Cycle

2 seconds during the discharge time of C-67. This delay keeps the play and rewind motors energized for a short period of time (through auxiliary switching not shown). This is done to eliminate any tape travel when the capstan and flywheel coast to a stop.

"Fast Forward" Operation

For "fast forward" operation the FAST FORWARD button S-6 (Figure 9) is depressed to operate forward motor B-4 and forward relay K-13. C-73 serves to filter the d.c. and provides a delay for the release of K-13. The FAST FORWARD switch puts full power across forward motor B-4, causing it to rewind the tape on the forward spool; when this switch is released, the power is removed from the "fast forward" motor. However, release of relay K-13 is delayed for 2 seconds by C-73, permitting a d.c. voltage to be impressed across the rewind motor for this period —thus bringing the unit to a stop.

Rewind Operation

When the REWIND button is depressed, the rewind relay and the memory relay are operated. Power is supplied to the rewind motor, B-3, which rewinds the tape from the take-up reel to the supply reel. When the STOP button on the control panel is depressed, or when the elapsed-time indicator reaches the "O" position, power to the rewind motor, B-3, is disconnected. However, because dropout of the memory relay is delayed for approximately 2 seconds, d.c. is applied to the supply reel (forward motor), bringing the machine to a stop. The purpose of the memory relay is to tell the machine whether to apply the d.c. power to the forward motor or to the rewind motor, depending on whether the Answering Set is in "fast forward" or in "rewind".

Conclusion

Our Model LP Electronic Secretary Telephone Answering Set is designed to as nearly as possible duplicate the subscriber's actions in his absence. Sectional construction has been employed as much as possible. The transport mechanism is plugged into the main chassis and may be completely removed for servicing. Printed-circuit boards are provided that plug into the main chassis. Portions of the amplifier and switching circuits, such as voice control and talk down tone, may be omitted if desired. Other optional accessories, such as the headset and foot control, are detachable from the outside of the cabinet, as is the microphone. This answering set is designed for simplicity and efficiency in operation.

E. A. Marheine graduated in Electrical Engineering from the University of Michigan in 1949. He spent three years in Kansas City, Missouri, working for Bendix Aviation and General Motors. While at General Motors, he was a Process Engineer on the Thunderstreak F84F aircraft project. He was a Project Engineer for the Bell Sound Systems in Columbus, Ohio. For the last five years he has been the Assistant Chief Engineer of Electronic Secretary Industries, Inc. He holds one U.S. patent on a voice control unit and has two applications pending.

THE 57A MICROWAVE PATH PROTECTION SYSTEM

By D. H. Hesselgrave
Lenkurt Electric Company

The 57A Microwave Path Protection System is a fault-sensing and transmission-switching system that serves as an automatic guardian of transmission quality on broad-band radio channels. It will detect a loss of transmission level, or an increase in noise, in any one of up to three channels, and will transfer the communications traffic from this channel to a normally idle stand-by channel. To meet the requirements of data-transmission traffic, the transfer is made without interruption or level change.

The casual observer must find the designer of a microwave radio system to be a pessimistic soul. He hardly ever installs just one radio system; there invariably is a second one running right along in parallel—a silent partner standing by to take over in case of failure.

This lack of faith in a radio channel's reliability is entirely justified. The broad communications highway through the sky is vulnerable to a variety of attacks. Equipment failures occur, and human frailties cause interruption; but the elements themselves represent the most formidable attack force: the layers of shifting air currents split the radio path into a number of ducts, each having a slightly different length. The radio signal follows these paths, but in recombining at the receiving end, the various components are no longer in phase. As a result, the cancellation of some of these components may greatly reduce the total signal strength, thus causing a "fade". At such time, the proportion of radio receiver output noise greatly increases.

Fortunately, this type of fade is frequency-selective, usually appearing as a severe signal loss in only one place at a time in microwave radio bands such as the 6,000-mc common-carrier band. This fact makes it practical to employ one redundant path—on a frequency well separated from the others—to protect more than one regular radio channel. A typical complete radio system installation will then consist of the regular radio channels, a stand-by channel, and a protection system to substitute the stand-by channel for the failed regular channel. The 57A Microwave Path Protection System was created to serve this latter purpose for Lenkurt Type 74A, 6,000-mc microwave radio relay systems, when they are installed in groups.

The entire 57A development was, of course, a team effort. The success of the mechanical design is due to the work of H. W. Ryner. Much of the novel circuit approach was contributed by J. P. Sicard. R. A. Heine has been involved with reduction to practice in all phases, and was a vital part of the field trial.

Functions

What is the nature of such a protection system? How does it know when a regular channel has failed, and how does it tell the transmitting end of the radio system that the receiving end is getting a substandard signal? These and many other related problems must be solved in the design of a protection system.

Figure 1. A complete 57A duplex terminal being tested by R. A. Heine. This view shows the compact unit construction of 57A equipment.

Let us consider first the monitoring function: How does the protection system distinguish between a "bad" and a "good" channel?

We know that a good radio system has a high signal-to-noise ratio; the presence of adequate signal level, and the relative absence of noise can then be the criteria for a good channel. Signal-presence monitoring is a simple problem; we can transmit a pilot tone—locating it outside the nominal message band of frequencies, so it will be easy to pick off at the receiving end. Sensing the noise on a channel is, however, a little more difficult; the noise energy must be sensed on a frequency band which is so restricted that neither the message channels nor the pilot will be mistaken for noise by the sensing circuit.

The latter problem can be solved by monitoring the noise energy which surrounds the pilot. To prevent any ambiguity, we consider the noise as sidebands, or modulation, of the pilot. The pilot is amplified in a broad-band circuit and detected — the detection process translating the pilot energy into d.c. The residual a-c noise modulation is further amplified and then rectified. The d.c. due to pilot, and the d.c. due to noise, are applied in opposition to the sensing circuit; either a decrease in pilot or an increase in noise will change the quiescent d-c level, thus indicating poor transmission. The 57A system uses these two parameters of signal and noise and performs the necessary transfer as required.

The 57A Microwave Path Protection System consists of three main parts:

1. A sensing unit, located at the receiving end of each channel to constantly monitor the quality of transmission on that channel, and to even anticipate (in cases of fades) the need for transfer to the stand-by channel.

2. A switching unit to transfer the input and output baseband connections from a regular channel to the stand-by channel in the event of failure of the regular channel (or of an unacceptable level of noise on it), and to automatically return transmission to the regular channel when its condition returns to normal. Because switching is at constant level and on a "make-before-break" basis, users of the channel are not aware of the transfer.

3. A control path between the sensing unit at the receiving end and the switching elements at the transmitting end of the radio system.

A complete 57A system includes, at each terminal location, equipment for transfer of both transmitting and receiving channels. (It protects each direction of radio transmission independently, since failure generally occurs in only one direction at a time.) Such a "duplex" terminal provides also the common equipment, such as the power supply, some alarm functions, and certain relay-rack hardware which is shared by both the transmitting and the receiving transfer equipment. Where special applications require path protection for only one direction, equipment for transfer of transmission only at one end, and reception only at the other, can be supplied.

Figure 1 illustrates a duplex terminal. The "transmit" equipment is at the top; the "receive" equipment, below. Note that each unit is complete, even to test facilities. The only additional equipment needed for lineup and test is a high-frequency vacuum-tube voltmeter.

Transmission Path

The transmission path of the 57A system appears in Figure 2. Here you will find only those elements which carry the communications circuits requiring protection.

Notice that only passive elements are in the transmission path; failure rates in such items as relays and filters are expected to be less than the

failure rate of the active circuits, such as transistors or electron tubes. Furthermore, in case of power supply failure, all circuits simply return to normal. With passive elements and relays in the switch units of the 57A system, transmission circuits can still loop through the protection system with no interference.

The elements in this transmission path establish the frequency limits of the transmission band. The low-end limit of 12 kc is set by the pass-band characteristics of a hybrid transformer in the transmitting switch unit. The upper frequency limit of 1,300 kc, which is compatible with that of the Lenkurt 74A Radio Relay System, is prescribed by the pilot pick-off filters in the sensing circuit, to be discussed later. The switch unit relays will, of course, transmit down to d.c. and maintain excellent crosstalk and impedance characteristics up to the high frequency limit of the band.

As previously mentioned, the 57A system verifies transmission continuity by monitoring a pilot. This pilot is applied to the system through the band-pass section of the transmitting filter, rides through the radio system along with the baseband messages and is then picked off by the band-pass section of the receiving filter. A pilot frequency of 1,570 kc eases the problem of filtering out the pilot from the baseband message circuits. The pilot is now fairly well separated from the 1,300-kc top frequency of the message circuits, yet will pass over the radio system without suffering excessive high-frequency "roll-off".

All the elements of the 57A system serve one main purpose: control of the transmission switches. When a regular channel fails, the switches must operate to substitute the stand-by protection channel.

The transmitting switch for the 57A system is

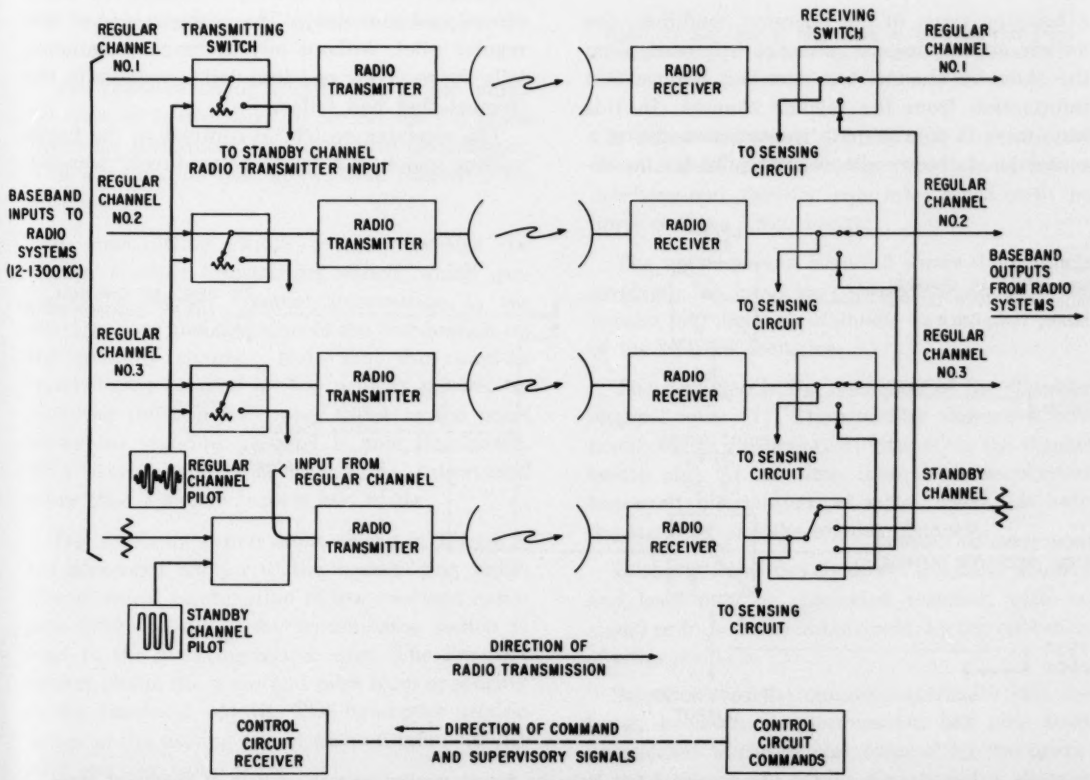


Figure 2. Transmission path of 57A system, showing three Regular Channels at the top, Stand-by Channel at the bottom, and the method of transferring traffic.

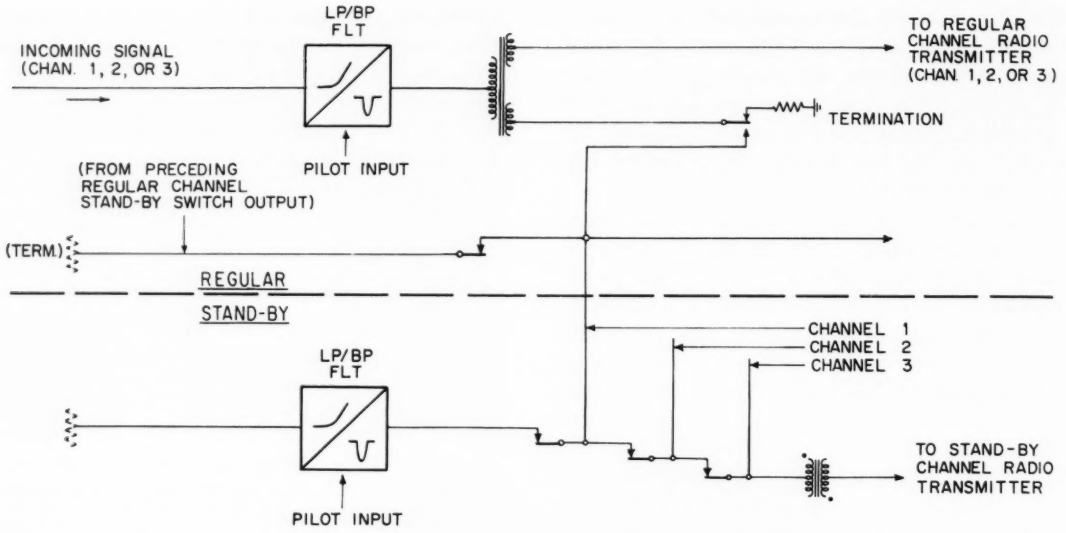


Figure 3. Simplified Schematic of 57A Microwave Path Protection System showing elements involved in transfer of Regular Channel Transmitter to Stand-by Channel Transmitter.

a bridging type; in the operated condition, the switch applies regular channel information on the stand-by channel but does not remove this information from the regular channel. In this way, there is parallel-path transmission during a protection transfer, with regular pilot for the receiving end to monitor. The reappearance of this regular pilot, without any accompanying noise, tells the receiving end that "all is well" with the channel that had failed.

The receiving switch, in contrast to the transmitting switch, is a "make-before-break" transfer-

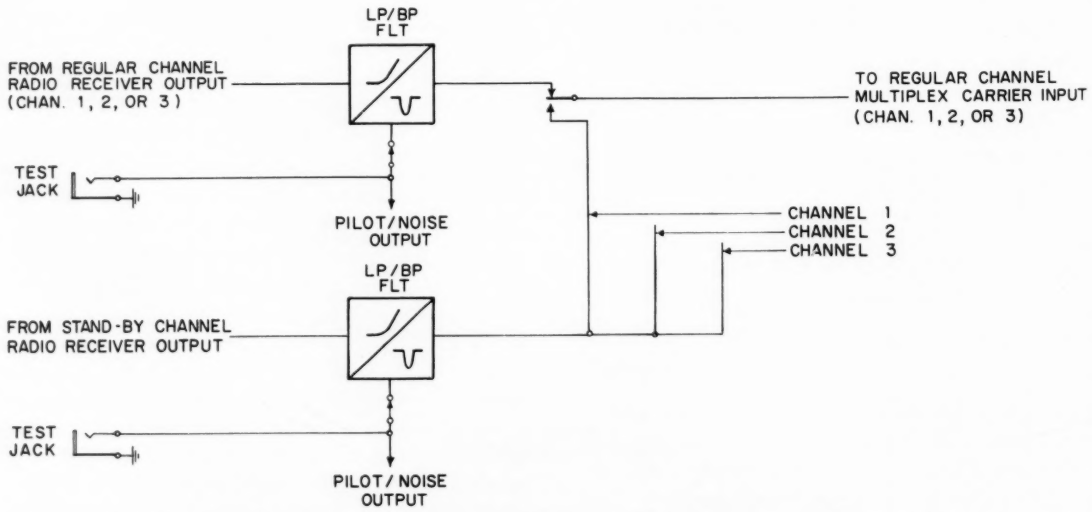


Figure 4. Simplified Schematic of 57A Microwave Path Protection System showing elements involved in transfer of Regular Channel Receiver to Stand-by Channel Receiver.

type switch, and is connected either to the regular channel or to the stand-by channel, but never to both, except during switching. The receiving switch must, of course, operate in this manner so that any high noise or other circuit disturbance failure that accompanies a failed regular radio channel cannot be fed into the drop during stand-by channel operation.

Now let us examine the actual switching circuits. Figure 3 gives a simplified schematic of the transmitting switch. The contacts for both the transmitting switch and the receiving switch are made by conventional short-frame telephone-type relays. These relays have been equipped with gold contacts and with extra grounded springs for additional crosstalk protection.

The baseband input to the regular channel radio system passes through a low-pass filter which cuts off at about 1,350 kc. This filter blocks any noise or false pilot which has originated either in a previous 57A system or as a spurious product of a carrier system. The input to the stand-by channel is derived from one winding on the hybrid transformer, which is normally terminated.

The phase-reversing transformer in the stand-by channel is necessary to correct for the phase inversion introduced by the hybrid transformer. This combination then gives phase coherence for all channels.

A transmitting switch request operates the regular channel transmitting switch, which connects the regular channel information to the stand-by line and disconnects the termination on the stand-by channel. Note that the stand-by channel may be used for low priority service, by applying the fourth channel input to the point where the stand-by channel is now terminated. This service would, of course, be interrupted every time a switch request was made.

The receiving switch units, shown in Figure 4, are somewhat similar to the transmitting units. The identical combination of low-pass and band-pass filters found in the transmitting switch is used in the receiving switch unit. The low-pass section blocks the noise and pilot from appearing at the baseband output. The band-pass section serves as the sensing circuit pick-off point for the pilot and associated noise.

The operation of the receiving switch is actually a four-step procedure. Figure 5 illustrates the chronological switch sequence and shows how a receiving-end transfer can take place with no break and no level-change.

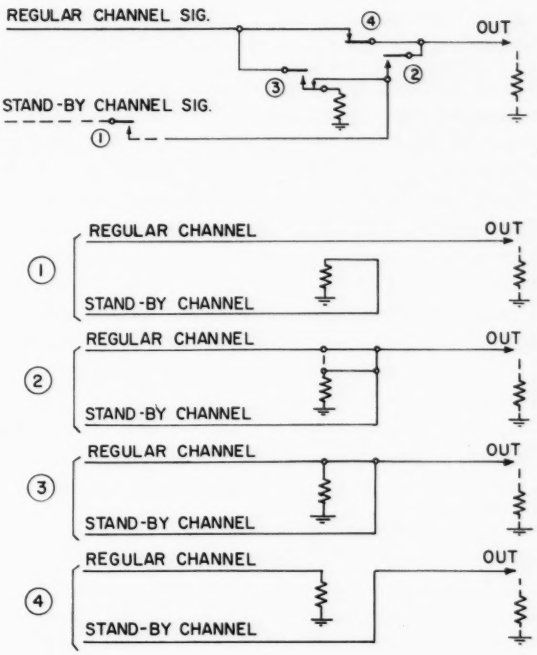


Figure 5. Sequence of four steps in Receiving-end Transfer, providing "No-break, No-level-change" operation.

The upper part of Figure 5 shows the contacts involved; the lower part shows the status of the regular and stand-by channels during each phase of the transfer sequence.

The first step is the operation of the stand-by channel relay (1). The stand-by channel is now connected to a termination internal to the regular switch unit. At this time, there is phase-coherent baseband information, at equal levels, on both the stand-by and the regular channels.

In step 2, these two signals of the same polarity and level may be connected together, with no signal or impedance impairment, by the operation of relay contacts (2).

Step 3 leaves the circuits electrically still the same; however, the termination has now been transferred to the regular channel by the operation of relay (3), while the stand-by channel remains connected directly to the regular chan-

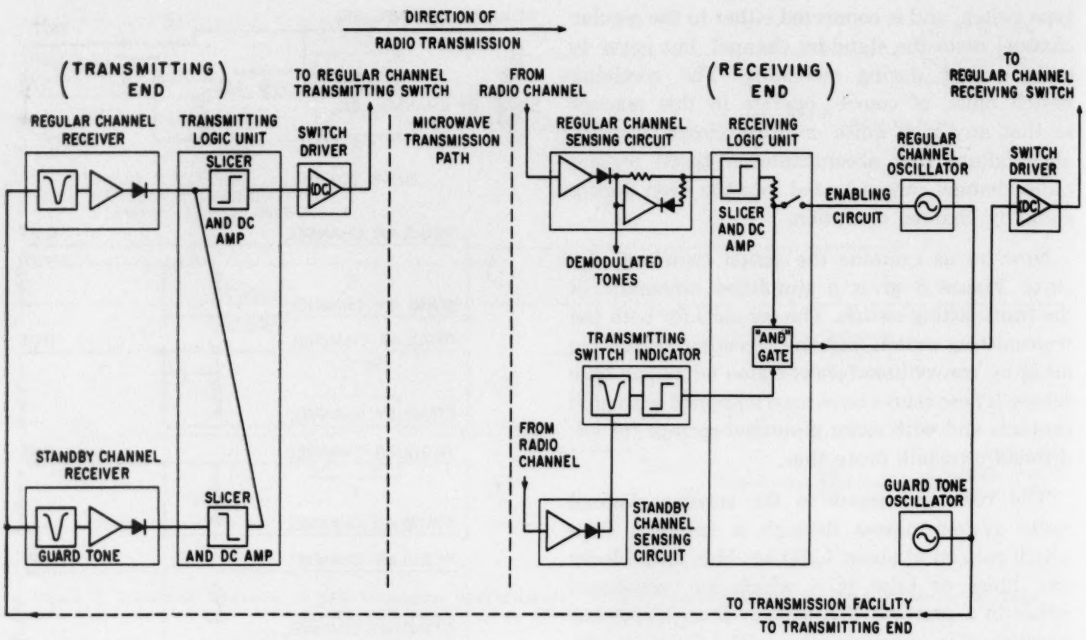


Figure 6. Block diagram depicting control circuits of the 57A Microwave Path Protection System.

nel output. In step 4, relay (4) opens this connection between the regular channel and its output, leaving the stand-by channel tied to the output. The regular channel is now connected only to its internal termination.

Each channel is equipped with a bridging-type test jack. In normal service, this test jack serves as a convenient monitoring point for pilot-tone. If the switch of the test jack is opened, an externally produced pilot-tone and artificial noise can be injected into the sensing circuits for purposes of alignment or maintenance. (By cutting off the pilot-tone, the operation of the test-jack switch on any channel initiates a transfer of that channel to the stand-by channel.)

Control Circuits

With this background of the transmission path in mind, let us now see what goes on "backstage." What decides when the switches shall operate, when they shall release, and when they must be locked out? These functions are handled by the control circuits, shown in block form in Figure 6.

To better understand the control circuit functions, let us follow a switching sequence resulting from a radio channel failure. The sensing circuit will recognize this failure (which will either be a drop in pilot level or an increase in noise, or both) and will translate it to a change in d-c level, as previously described.

This level change is applied to a "slicer", or "Schmitt trigger" circuit, which assures a positive-action switch, without jittering. The slicer output level remains constant until the input level exceeds the critical point; it then trips, and gives a large change in output level. It remains in this state until the input level falls below the first critical point to a second critical point, at which time the slicer reverts to its original output level. The difference between the two critical points is termed the "slice", and can be adjusted as necessary for whatever degree of inertia, or hysteresis, is considered necessary. A very thin slice will cause system jittering during marginally-good transmission periods; too wide a slice will require a great improvement in transmission

before the equipment transfers from stand-by and returns to a regular channel.

The slicer output is applied to the receiving logic unit. The d-c amplifier associated with the failed channel now conducts and simultaneously back-biases the d-c amplifiers in the other channel inputs. This action locks the other channels into an artificial "good" condition, so no multiple switching action can now take place. In the event of simultaneous failure of more than one channel, the channel to be protected is chosen purely fortuitously, depending only upon chance variations in nominal circuit constants.

With the turning on of the d-c amplifier in the failed channel, an "enabling" signal is applied to a VF channel oscillator and an input is applied to an "and" gate. This VF signal (at a different frequency for each of the regular channels) goes back to the transmitting end of the 57A system to identify the regular channel that has failed. Accompanying this signal over the return path is a guard tone, which is always on and may be monitored at the transmitting end for a fail-safe check of continuity of transmission on the return path from the receiving end.

With the normal two-way 57A installation, the command and the guard signals are carried back to the transmitting end by the complementary 57A system. The return control path over radio is, of course, no more reliable than the forward transmission path being protected. For that reason, the control tones are applied as modulation to all regular channel pilots and the stand-by channel pilot simultaneously. These pilots are picked off at the far end of the system, detected, and then added together to furnish a single control-tone source. Should any one of the return paths fail, its control tone output and associated source impedance are disconnected from this common bus, to keep them from introducing noise into the control tones and to minimize the level change which would otherwise be caused by the loss of one of the return paths.

The common control-tone output bus is connected to all channel receivers of the 57A system at the transmitting end of the radio system. Each receiver is tuned to the frequency of its associated channel oscillator. The regular channel receiver passes the channel oscillator signal, amplifies it, and drives a slicer which applies the resultant d.c. to the transmitting logic unit. At the same time, the guard tone oscillator signal undergoes similar treatment in the stand-by channel.

The transmitting logic unit is identical to the front part of the receiving logic unit. The logic is supplied by the slicers driving interconnected d-c amplifiers. Should the guard tone and also a regular channel VF tone be present, the associated regular channel slicer and d-c amplifier will deliver a d-c control current. This is further amplified by the switch driver unit and is then applied to the regular channel transmitting switch. As previously shown in Figure 3, the operation of this switch bridges the regular channel baseband input on to the stand-by channel to establish the parallel transmission path previously mentioned. This switching action removes stand-by channel pilot and applies regular channel pilot to the stand-by channel.

Although these two pilots are derived from a common crystal-controlled 1,570 kc generator, they have one significant difference. The regular channel pilot has a 4-kc modulating tone, whereas the stand-by channel pilot has no modulation. When a transmitting switch is made, the modulation on this regular channel pilot can thus notify the receiving end of the radio system that the stand-by channel is carrying regular channel information. By this means, we can be assured of true sequential action: the receiving switch will not operate until it has the stand-by facility available for the transfer.

Returning to Figure 6, we find a sensing circuit for the stand-by channel at the receiving end of the radio system; this circuit is, in fact, identical to that for the regular channels. The regular channel pilot is picked off at the receiving end of the stand-by radio system and detected. This, of course, is part of the signal-quality monitoring, just as is done with each of the regular channels. However, the stand-by channel has an extra circuit tied into this demodulated tone output. This is a 4-kc band-pass amplifier which is looking for the presence of the regular channel identifying modulation. When this modulation appears, it is amplified and rectified, and then operates a slicer in the transmitting switch indicator unit. This slicer applies the second input to the "and" gate which then delivers an output to the d-c amplifier to operate the regular channel receiving switch. The protection transfer is now complete. The entire switching system will remain in this

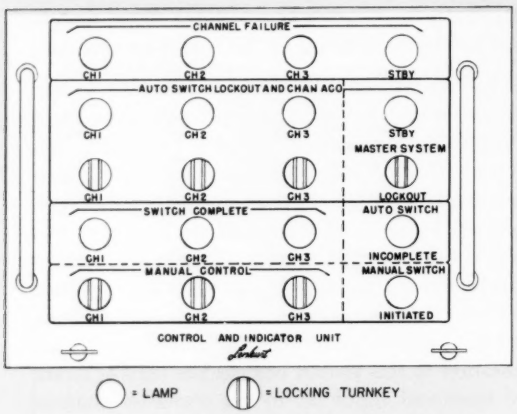


Figure 7. The 57A Microwave Path Protection System's Receiving End Control Panel.

condition until the regular channel is restored to a "good" condition. At that time, all functions just discussed will reverse, and the system will return to normal to await the next trouble signal.

The entire switching sequence from the moment of sensing a circuit request takes approximately 60 to 70 milliseconds. Because of the effect of transient-voltage suppressor circuits across the relay coils, the restoral time, following an automatic transfer, is about 100 milliseconds.

If the stand-by channel had failed before the protection transfer was requested, the transmitting-end switching operation would be completed, but the receiving end would not be transferred. If the stand-by channel fails during the switching operation, the receiving-end switch will fall back to the regular channel. Should the power fail at either the receiving or the transmitting end at any time, all switches will fall back to their normal straight-through condition.

In the event of simultaneous failures, one channel will be protected and the second channel will have to wait its turn. As soon as the first channel becomes good, there is a 150-millisecond delay in the receiving logic unit to prevent any switching operations while circuits and relays return to normal. At the end of this interval, the receiving end logic unit will again be "open for business", and the "and" gate will accept a transfer request from any regular channel.

Alarm and Control Circuits

Each significant operation of the 57A protection system actuates a circuit indication light, or an alarm, if required. Figure 7 shows the major indications, as well as the manual control provided in the 57A system. Each channel-failure lamp across the top is operated by a two-stage d-c amplifier which follows the sensing circuit. Any one channel which has failed for more than 30 seconds will bring in a minor alarm, in addition to this lamp. Concurrent failure of any two channels will immediately bring in a major alarm. The next set of lights and turn keys permits locking out any or all channels. Under this condition an automatic transfer will not take place and the alarm associated with the channel failure will not be activated.

The "switch complete" lamp, as the name implies, shows when the entire switching sequence is completed. In the event a transfer request is made, but is not followed within 200 milliseconds by a receiving-end transfer, the "auto switch incomplete" light will come on and will simultaneously bring in a major alarm.

The bottom row of keys permits manual transfer of any channel to the stand-by channel. This transfer will not override an automatic transfer, and will be completed only if the stand-by channel is idle. Should the operator wish to manually

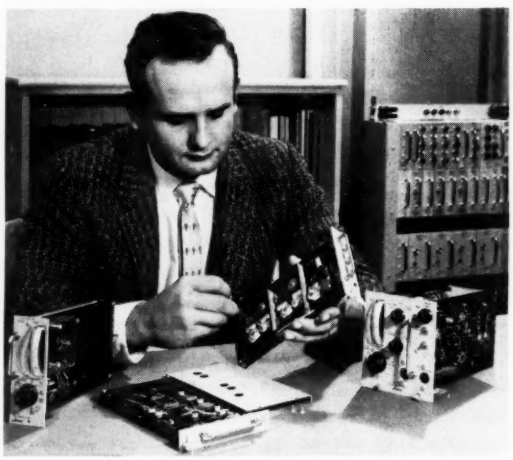


Figure 8. J. P. Sicard with some of the typical 57A plug-in units showing construction details.

switch one channel when another has been automatically transferred, he must first restore and lock out the latter channel with the AUTOMATIC SWITCH LOCKOUT key.

To avoid any ambiguity or misunderstandings in the various control functions, all operating controls are restricted to the receiving end of the 57A system. The transmitting end of the system has only one indication—a lamp which shows that a transmitting-end switch has been made—and one control—an alarm cutoff key to silence the guard-tone failure alarm.

Salient Features

The 57A system was the first Lenkurt apparatus to appear in the "bookshelf" or "computer-type" package. This mechanical construction is a natural evolution which places a maximum number of components in a given volume and still maintains easy access and economical production. Such considerations as flat sheet metal faceplates for simple forming and marking, modular-width and constant-height units for maximum mechanical part interchangeability, "stitched" wiring for rugged, reliable component mounting and connection, and sheet metal fasteners for captive, shakeproof mounting, all help achieve the above goals.

The mechanical construction may be seen in Figure 8. This type of construction permitted placing 103 transistors and 88 diodes, with little crowding, into four shelves occupying a total space of 14 rack units, for a duplex 57A terminal. All units are plug-in, with access to transmission input and output circuits on an associated jack field; parallel jacks on this strip permit patching out of any channel without loss in circuit continuity during the operation.

Simplified Requirements

The line-up and trouble-shooting requirements have been simplified by including integral test sets in the transmitting and receiving sections of the 57A system. These permit checking a total of 49 significant points throughout the system on a switched basis, with values read on the internal meters. The only external piece of test gear required is a 0-1.5 mc a-c high-impedance voltmeter.

To overcome the problem of heat rise due to internal power dissipation in these compact assemblies, the entire system was designed for a minimal power dissipation: 21 watts under normal service, and a maximum of 50 watts when in a full-alarm, all-channels-failed condition.

All equipment may be maintained from one side of the shelf; this permits back-to-back relay rack installations. The terminal blocks are on a pull-out slide to facilitate central office connections. All coaxial cable circuits are wired directly to connectors in the relay rack duct, to maintain constant impedance and shielding.

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EXTENSION OF TYPE A SATT SYSTEMS *to Direct Distance Dialing*

By W. A. Rust
Automatic Electric Laboratories, Inc.

The Type A SATT (Strowger Automatic Toll Ticketing) System, first of the present SATT systems, is intended for use in large metropolitan areas where worthwhile trunking economies can be realized through its use of Director Register-senders (Figure 1) in conjunction with translating circuits for automatically routing calls independently of the dialed office-code digits. This article will discuss, briefly, what has been done to convert the Type A SATT Systems in the metropolitan Los Angeles area (where all but two of the existing Type A SATT Systems are installed) for use in the nationwide Direct Distance Dialing (DDD) network.

Actually, two versions of the Type A SATT System are in use today. The first is known as the Type 48 SATT System; a later version is called the Type 53 SATT System. The provisions made for conversion in each of these systems will be described separately.

The Type 53 SATT System Anticipated DDD

Design of the Type 53 SATT System was begun in the early 1950's. By then, direct distance dialing by operators was a well-established practice, and plans for extending the service to telephone subscribers were well under way. Even

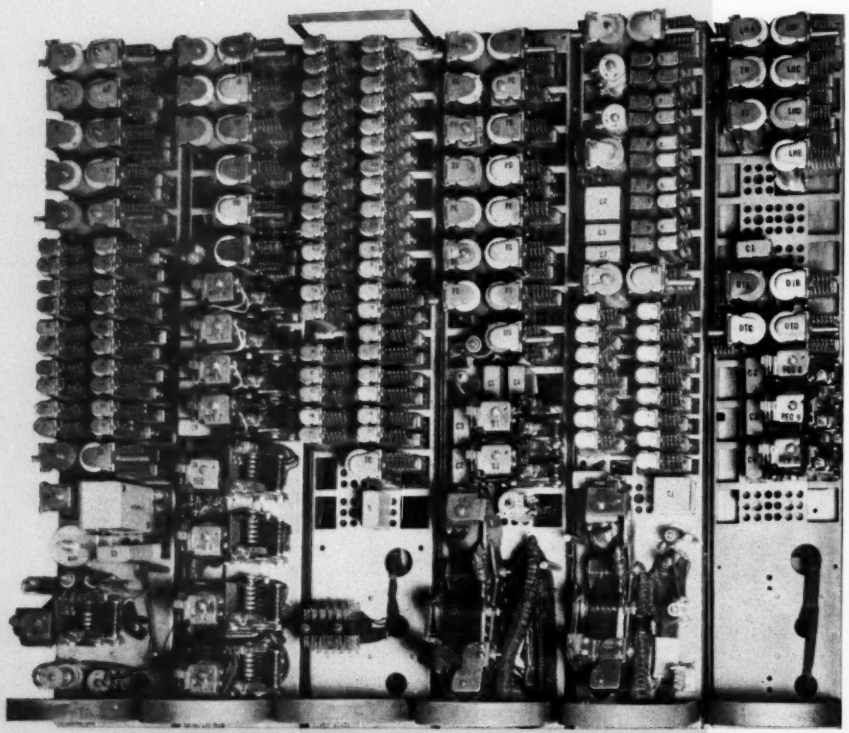


Figure 1. Type 53 Director, highlighting (right) the Toll Register added for DDD. Digit registers 1-7 are in the unit second from the left. Digit registers 8-10 are in the Toll Register, along with other DDD control relays.

though the Type 53 system was initially designed and installed as a seven-digit short-haul system, it was possible at the time of its initial design to anticipate a number of DDD requirements and to include them or make provision for their addition at a later date (Figure 2).

Inasmuch as the Director Register-senders would be required to function on both short- and long-haul type calls (i.e., seven- and ten-digit called numbers), provisions for future DDD were concentrated in these units. The principle features which were anticipated and incorporated in the initial design of the Directors for Type 53 SATT were the following:

1. Means for recognizing Numbering Plan Area (NPA) codes and conditioning the Director for ten-digit called-number operation.

2. Means for rechecking the calling station identity on DDD calls.

3. Arrangements for storing and sending three additional digits on DDD calls, both for routing and for billing information purposes.

4. Space for adding the necessary extra digit-registers and control relays.

In general, provision for these anticipated requirements was made by including necessary wiring and cabling in the initial design of the Director. Digit registers 1-3 were equipped with extra levels to provide the NPA code-recognizing feature. Two additional relays were included in the initial design of the Call Recorder portion of the Director, to facilitate the change-over from seven- to ten-digit operation. Also, certain test facilities of the Type 53 SATT monitoring system were arranged, in advance, for ten-digit operation.

Hence, in order to convert these Directors to DDD service, the principal added equipment consisted of the digit-registers and control relays referred to above under items 3 and 4.

Calling Party Identity Recheck

The Type A SATT System provides for automatic number-identification on party lines with up to five main stations. Identification of the calling station requires the dialing of a digit having the value of two, or higher, as one specific digit of the called number. As the first two digits of an office code cannot be lower than 2, this requirement was always met, on short-haul calls, by identifying either the first or the second digit of the called number—in the Type A system, the second digit.

Since it was possible, however, that an NPA code might have a 1 as the middle digit, it was necessary, on DDD calls, that party identity be re-examined on some other digit. To meet this requirement, the Director was arranged to shift its party-registration function from the second to the fourth digit on such calls.

Six-digit Translations

In the early stages of planning for DDD in the Type A SATT Systems, it was expected that all traffic for points outside the originating NPA would be dispersed via individual control-switching points (CSP) for nearby areas and via a common control-switching point for distant areas. It soon became apparent, however, that the diminishing size of heavily-populated Numbering Plan Areas, together with continued outward expansion of metropolitan communities across NPA boundaries, would make the single-dispersal-point idea impractical for traffic destined to nearby Numbering Plan Areas.

In many instances in the Los Angeles area, direct trunks were already in existence, between some offices that were to be separated by an NPA boundary, so routing calls between such points via some centrally located CSP for the adjacent area would have entailed needless, uneconomical back-hauling.

It can be readily appreciated that if a selection must be made from more than one route into an NPA, based on the destination in that area, it becomes necessary to examine the office-code digits as well as the NPA code. This technique of making a routing choice based on the NPA and the office code digits, together, is known as a six-digit translation. The facility for making six-digit translations was one of the principal features which had to be added on the Type 53 SATT System at the time it was converted for DDD use.

The method of securing six-digit translations in Type A SATT Systems is significantly different from that used in the later access-code-type SATT systems. In the latter, a limited num-

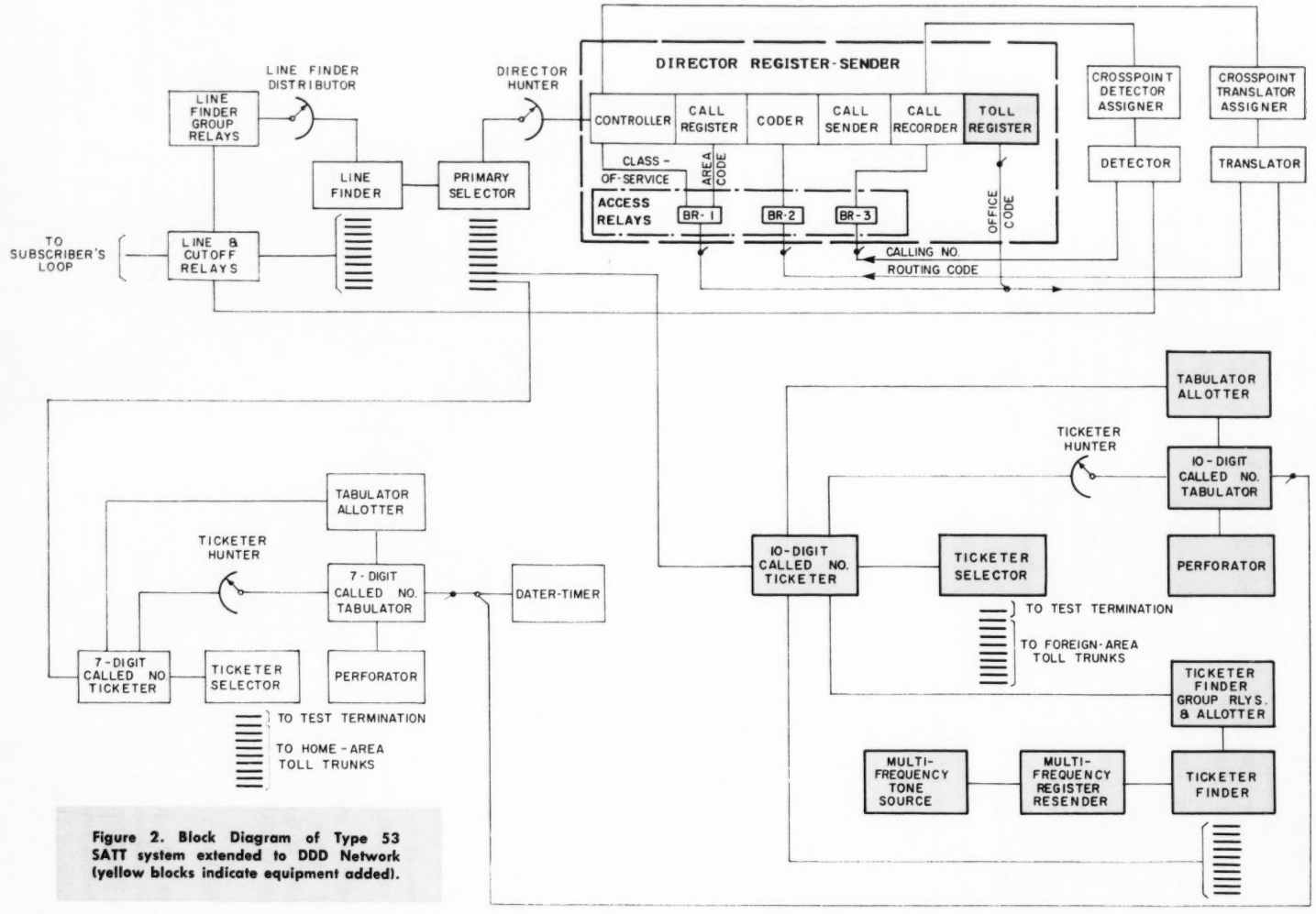


Figure 2. Block Diagram of Type 53 SATT system extended to DDD Network (yellow blocks indicate equipment added).

ber of specific NPA codes requiring six-digit translations are recognized in the Transender, and a specific NPA code marking is furnished to the Translator, along with the called-office code marking. The Translator then furnishes the required routing information as a result of an integration of these two markings.

On a DDD call in Type A systems, the NPA code is first offered to the Translator, and from it the Translator determines whether the NPA code alone is sufficient to derive a routing, or whether a six-digit translation is required. Assuming, for the moment, that a translation is made after six digits have been dialed, the Translator makes a temporary note of what NPA code has been received, and instructs the Director to drop the NPA code and substitute the office code to the Translator. Within the Translator, an integration is then made of the temporarily stored NPA code and the called office code, in order to derive the proper routing.

As a consequence of concentrating in the Translator circuits the recognition of six-digit translations, there is no circuit limitation on the number of NPA codes which can be given six-digit translation service. It is merely necessary to equip the Translator with the necessary relays and a jumper field for each NPA code requiring six-digit translations. Equipment provisions have been made, at this time, for six-digit translations of four NPA codes on the Translator racks of the Type A SATT installations now being converted for DDD service.

Class-of-service Markings

Another distinction of the Type A system is its facility for discriminating between various classes of service, and varying the translated information accordingly. For example, what may be a toll call for a flat-rate subscriber may be a free-service call for an Extended Area Service (EAS) subscriber.

Or, again, it is often necessary to block pay-station users from points which are dialable from residence or business telephones. Such discrimination is accomplished in the Translator by means of proper class-of-service marking.

Due to the proximity of adjacent areas in many of the locations where Type A SATT Systems are used, it is anticipated that originating class-of-service discrimination will be required on six-digit translated calls to these adjacent areas.

The Type A SATT Systems being converted for DDD are arranged for three class-of-service markings, and facilities for making translation discriminations based on these three classes of service have been carried through to the four NPA codes arranged for six-digit translations. To permit earlier sending on DDD calls when six-digit translations are not required, the Director used for Type 53 SATT is arranged to make a translation attempt after only four digits of the called number have been dialed. Where the NPA code alone is sufficient for routing, the translation is completed at that time; otherwise, a "come again after six digits" marking is returned to the Director. In the latter instance, the Director again associates itself with the Translator after six digits have been dialed, and the translation is accomplished as described previously.

The Type 53 SATT System can receive up to six routing digits from its associated translator. The Translator can also furnish markings to the Director Register-senders to control the deletion of parts of the called number as illustrated in Table 1.

The routing digits are used as required for routing the calls through the switching ranks in the SATT office of origin, and may also, in some instances, be used for controlling a switching operation in a distant tandem office.

Where a DDD call is to be passed to a CSP for completion, either seven or ten digits of the called number will usually be sent forward. The facilities for sending only four or five digits of the

Table 1. Translated forms of called number for DDD Type 53 SATT System

MAX. NO. OF ROUTING DIGITS (MIN., 1)	AREA CODE	OFFICE CODE	TERMINAL DIGITS
XXXXXX	X 1/0 X	ABC	XXXX
XXXXXX		ABC	XXXX
XXXXXX		C	XXXX
XXXXXX			XXXX

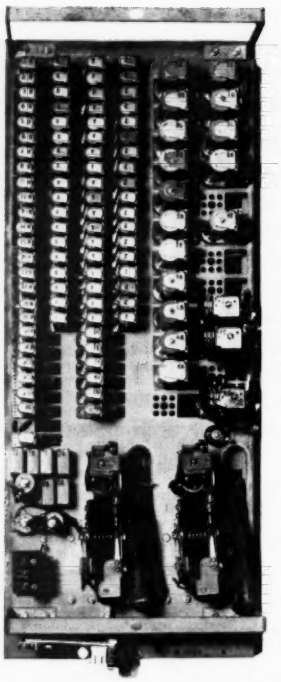


Figure 3. Ten-digit Ticketer circuit used in Type 53 SATT System, showing storage relay groups for calling party's number (1-5), Director Identity (6-8), called party's number (21-20), timing switches (PC, MC, & MT), "in" and "out" sequence switches (REC and SEND), control relays, and miscellaneous apparatus. Ticketer used in Type 48 SATT System is similar, but substitutes an Assistor Identity storage group for one of the Director Identity groups shown above, and differs slightly in its control relays and miscellaneous apparatus.

called number will usually be used only on those calls which are direct-trunked to an adjacent-area end-office.

The switching arrangements for DDD calls in the Type 53 system (Figure 2) follow quite closely the established pattern for short-haul, seven-digit calls. Indeed, for a dial-pulse-sent call, the switching arrangements are identical, in the typical switching plan illustrated. Only the ticketing, tabulating, and perforating equipment differ, specifically to accommodate the ten-digit called-number information.

In many applications, the switching rank shown following the Ticketers is omitted, each Ticketer (Figure 3) being directly associated with a particular trunk circuit. In such instances, trunk group selection is made by the switching ranks ahead of the Ticketers, of which there frequently are more than the single rank illustrated. Ticketers used in this manner are said to be *high usage* Ticketers, since they are permanently associated with a trunk group engineered to maintain a high level of trunk occupancy.

Multifrequency Sending

Here, again, the Type A systems depart from the technique used in the access-code ticketing systems. In the latter, the multifrequency facilities can be included as an integral part of the Transender (which inherently is used only for toll traffic). Digits are outpulsed on a dial-pulse basis to reach a trunk circuit, after which the Transender switches over to multifrequency pulsing for the remainder of the digits that are to be sent to a distant office which is arranged to receive such pulsing.

In the Type A systems, multifrequency Register Resenders (Figure 4) have been used, on a pool

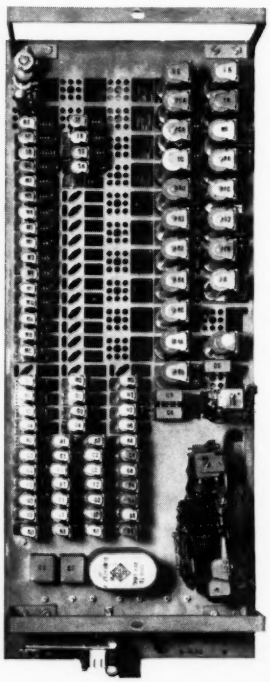


Figure 4. Multifrequency Register Resender used in Type 53 SATT System, showing digit storage groups (A-K), pulse counting relays (M1-M10), sequence switch (SS), repeating coil, control relays, and miscellaneous apparatus. Similar unit is used in Type 48 SATT System, but with an additional relay for distinguishing between seven- and ten-digit type calls.

basis, to avoid extensive modifications in the Director circuits, which would have been required on a relatively small part of their total traffic. Thus, the Director Register-senders pulse out on a dial-pulse basis, and when the interoffice trunk requires multifrequency sending, an MF Register Resender is engaged to receive and resend digits destined for the distant office. In the Type 53 system, multifrequency trunk groups are marked to the new Ticketers by a level marking from the associated ticketer-selector (or from the trunk circuit, when the Ticketer is connected directly to the trunk without an intervening selector rank). An immediate stop-dial is returned to the Director, and the Ticketer signals the ticketer-finder group relays that an MF Register Resender is required. A ticketer-finder locates the calling Ticketer and connects it to an MF Register-resender. The Ticketer then switches the pulsing lead from the Director to the MF Register-resender, which now receives the seven or ten digits of the called number. During this period, the multifrequency trunk circuit is held busy to local access, but the distant end is not yet seized.

Upon completion of Director outpulsing, the MF Register-resender signals the trunk circuit to seize forward, waits for the "delay-go" mark from the distant end—indicating that a sender is attached to the incoming trunk circuit in the distant office—and then sends forward the called-number digits, using multifrequency pulsing. Upon completion of multifrequency sending, the Ticketer releases the MF Register-resender, and waits for answer supervision from the distant office, in the usual way. Although Figure 2 illustrates the connection of a ten-digit Ticketer to the MF Register Resender for DDD calls, a seven-digit version of this same Ticketer is available to permit multifrequency sending on short-haul seven-digit calls where applicable.

Modification of Type 48 SATT

Inasmuch as the Director for the Type 48 SATT system had been designed considerably in advance of any subscriber DDD plans, it was not so favorably endowed with provisions for the addition of ten-digit facilities as was the Director for the Type 53 system. Space limitations required that an "assistance" approach be used, bringing in extra apparatus which was mounted elsewhere, to assist on DDD calls. The unit de-

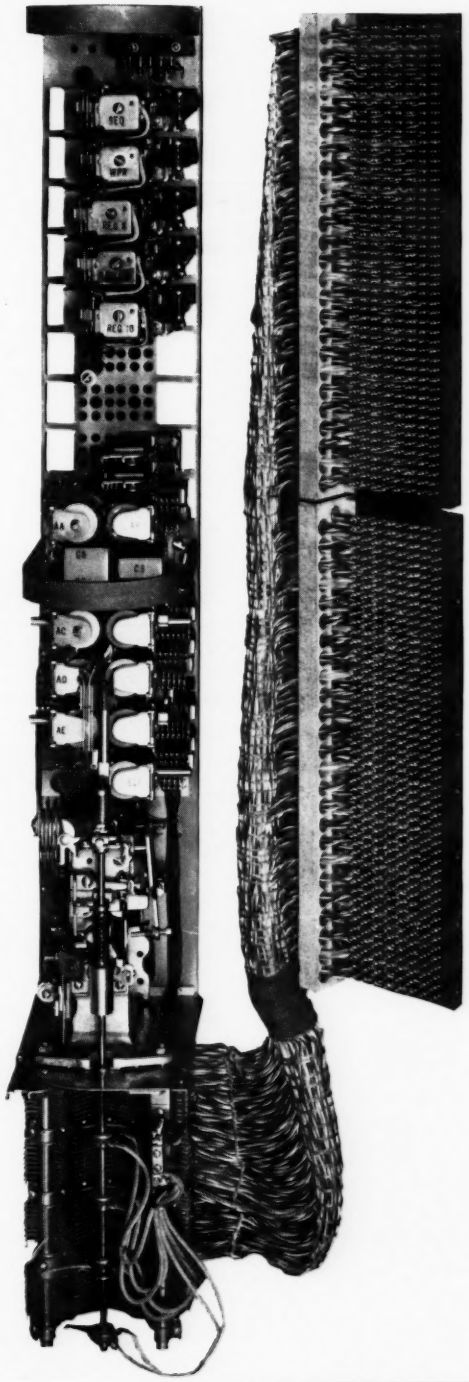


Figure 5. The Assistor used in Type 48 SATT System on DDD calls, with associated bank multiple terminal blocks at right. Called office code is marked on bank of Assistor, for use in making six-digit translations. Digit registers 8-10 for storage of digits beyond the capacity of the Director are located near the top of the Assistor.

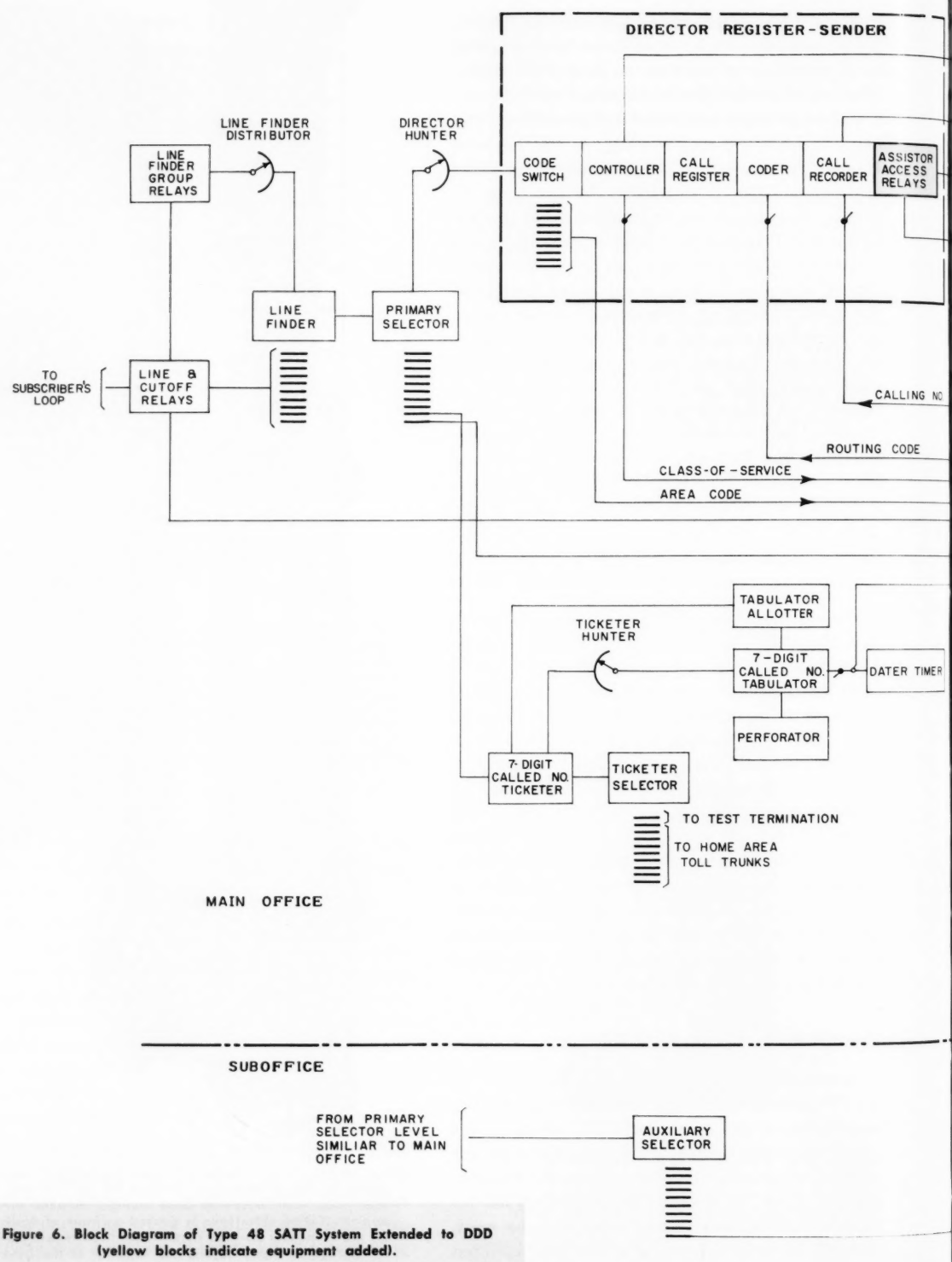
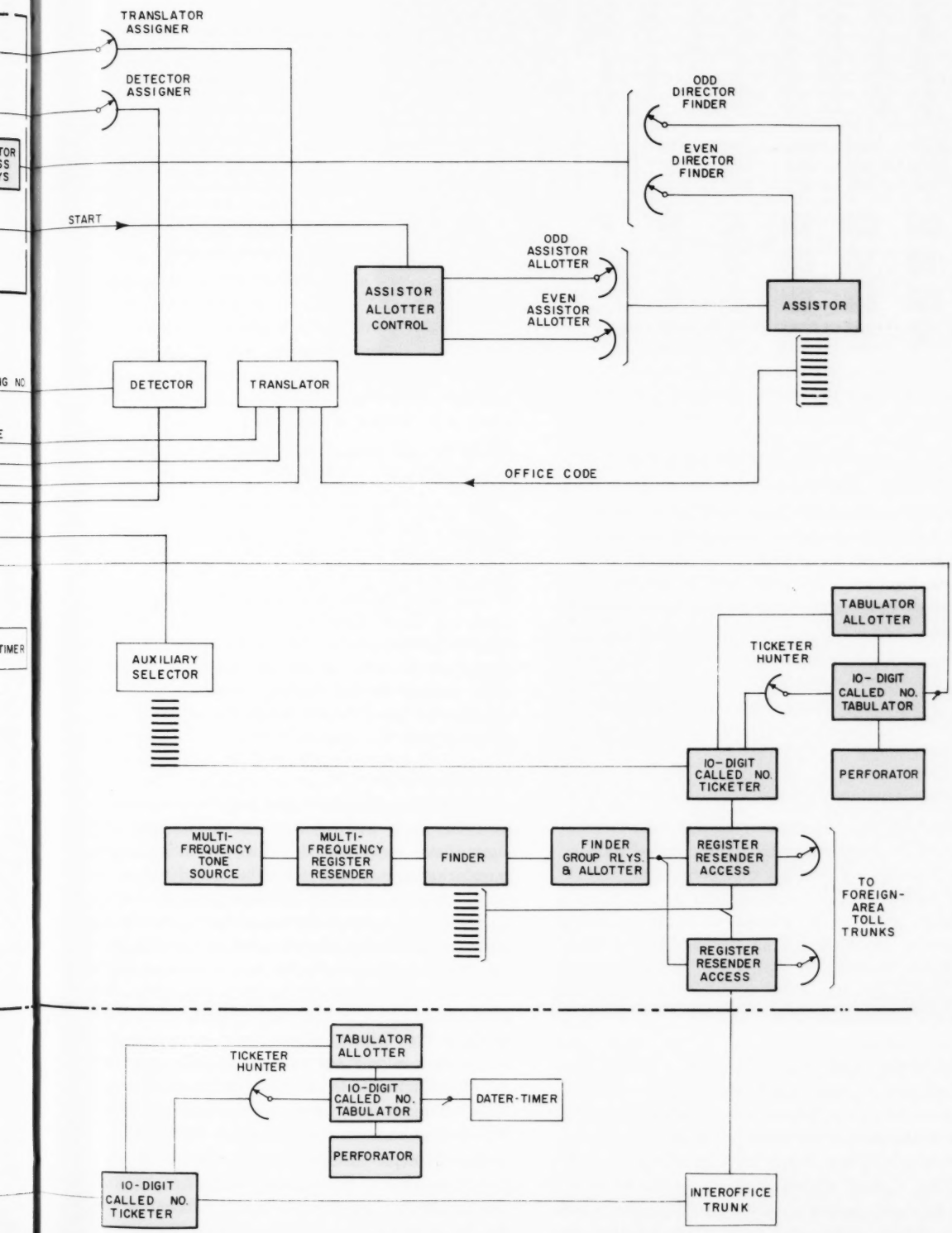


Figure 6. Block Diagram of Type 48 SATT System Extended to DDD (yellow blocks indicate equipment added).


TRANSLATOR ASSIGNER
DETECTOR ASSIGNER
ODD DIRECTOR FINDER
EVEN DIRECTOR FINDER
START
ODD ASSISTOR ALLOTTER
EVEN ASSISTOR ALLOTTER
ASSISTOR ALLOTTER CONTROL
ASSISTOR
DETECTOR
TRANSLATOR
OFFICE CODE
AUXILIARY SELECTOR
TABULATOR ALLOTTER
TICKETER HUNTER
10- DIGIT CALLED NO. TABULATOR
10- DIGIT CALLED NO. TICKETER
PERFORATOR
MULTI-FREQUENCY TONE SOURCE
MULTI-FREQUENCY REGISTER RESENDER
FINDER
FINDER GROUP RLYS. & ALLOTTER
REGISTER RESENDER ACCESS
REGISTER RESENDER ACCESS
TO FOREIGN-AREA TOLL TRUNKS
TABULATOR ALLOTTER
TICKETER HUNTER
10-DIGIT CALLED NO. TABULATOR
DATER-TIMER
PERFORATOR
10-DIGIT CALLED NO. TICKETER
INTEROFFICE TRUNK

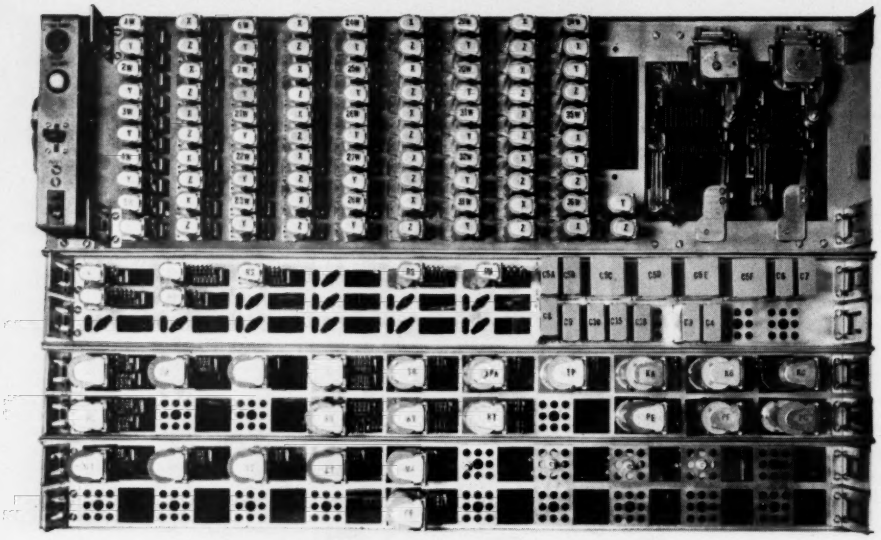


Figure 7. Tabulator used in Type 48 SATT System, showing storage relay groups for call data received from Ticketer. Tabulator passes Ticketer data together with additional information gathered from other sources to Perforator, where call data is punched on a paper tape. Tabulator for Type 53 SATT System is similar, but differs slightly in its storage groups, control relays, and miscellaneous apparatus.

signed to provide this assistance has been called the Assistor (Figure 5).

The Directors have been modified to initiate a call for assistance upon recognizing an impending NPA code, to recheck party identity on the fourth digit on DDD calls, and to accommodate ten-digit sending for both routing and ticketing.

Modification of the Director circuits (Figure 6) has involved both wiring and apparatus changes in the existing units, and the addition of a six-relay Assistor-access unit which controls most of the functions related to gaining access to an Assistor.

Assistor Operation

The call for assistance on DDD calls is initiated after the second digit of the called number has been dialed. The Assistor-access unit signals the Assistor-allotter control that an Assistor is needed, and one is allotted to find the calling Director. In the event an Assistor is not made available in time to receive the fourth digit of the called number, busy tone is returned to the calling subscriber.

The Assistor receives the fourth, fifth, and sixth digits, and stores them on a two-motion switch and a rotary switch, similar to the Director code switch, to provide an office-code marking for the Translator, in the event a six-digit translation is required. These digits are also stored on their regular register switch positions in the Director, for read-out purposes during sending operations. The eighth, ninth, and tenth digits also are received by the Assistor for memory storage on rotary switches.

For outpulsing, the Director processes all routing digits and the first seven digits of the called number, in the same manner as for a seven-digit call. On a DDD call, the last three digits cannot be sent until dialing is completed; the Director reads out these digits from the Assistor. In the event a special-service code in the x11 family is dialed, the Director cancels its call for assistance upon dialing of the second 1; these calls are handled by the Director without the aid of an addition like the Assistor.

Six-digit Translations

In the Type 48 system, the call for translation on DDD calls will normally be made after six digits have been dialed. Thus, when six-digit translation is required it can be completed on a single assignment to the Translator; there will be no need for the early translation and "come again after six digits" features provided in the Director for the Type 53 system. Up to the present time, however, applications of the Type 48 system for DDD have not required the six-digit translation facility. The Directors have been arranged, by means of a wiring option, to translate after the dialing of four digits, on DDD calls. If six-digit translation becomes necessary in these offices, it will merely be necessary to remove this option.

The Director of the Type 48 SATT System has a capacity of five routing digits. In addition, the Translator can furnish deletion controls for the Type 48 system as illustrated in Table 2.

Table 2. Translated forms of called No. for DDD Type 48 SATT System

MAX. NO. OF ROUTING DIGITS (MIN., 1)	AREA CODE	OFFICE CODE	TERMINAL DIGITS
XXXXX	X 1/0 X	ABC	XXXX
XXXXX		ABC	XXXX
XXXXX			XXXX

Ticketing and Allied Equipment (Figure 7)

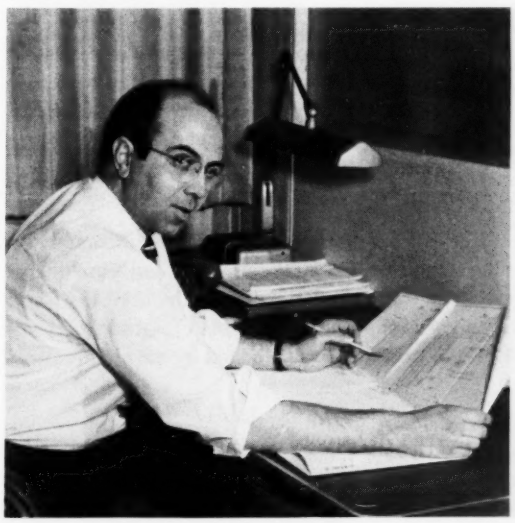
The ticketing, tabulating, and perforating equipment for DDD calls in the Type 48 system differs from that of the Type 53 system in its method of accessing the multifrequency pulsing equipment; in the Type 53 system, this equipment is accessed locally in each office by the Ticketers. In the Type 48 system, the multifrequency pulsing equipment is pooled in a main office for each exchange area, and is accessed by a special access circuit. For the present, all DDD traffic in the Type 48 system will be routed via the main office multifrequency trunk groups. This is not due to any inherent operating feature of this system but merely the incidental result of existing routing patterns for the central offices served by Type 48 SATT Systems.

In the Type 48 system, the Register Resender accesss relays, located in the main office of each exchange, replace the Ticketer function of gaining access to the MF Register Resenders, as described for the Type 53 system. They repeat the interoffice pulsing from the Directors to the MF Register Resenders (in the event of branch-office operation) or repeat the intraoffice pulsing from the Directors to the MF Register Resenders (in the event of main office operation). With this arrangement, the MF Register Resenders cannot recognize release of the Director, as they do in the Type 53 system. Hence, they are provided with a built-in means for recognizing whether to expect seven or ten digits by examining the second digit of the called number—and they commence outpulsing after receiving the appropriate number of digits. Release of the MF Register Resender is controlled by the Register Resender access relays, upon switch-through following the completion of multifrequency sending. To meet Via Net Loss requirements, this circuit also provides an optional 2-db pad for use on the main office access-relay circuits and those associated with interoffice trunks which do not provide at least a 2-db loss.

Conclusion

On March 5, 1960, Westwood office in the West Los Angeles exchange of the General Telephone Company of California was the first Type A SATT System office to be cut over to DDD service. Since then, this company has cut sixteen more offices onto DDD service, making this service available to some 175,000 subscribers served by these offices. All of these offices use Type 53 SATT System equipment.

More recently, the California Water and Telephone Company has placed seven offices, using Type 48 SATT System equipment, onto DDD service; these offices serve over 100,000 stations in the greater Los Angeles metropolitan area. Finally, the Sunland-Tujunga Telephone Company, also in the Los Angeles area, will extend DDD service to at least another 12,000 subscribers, using the Type 48 SATT System equipment. Thus, within one year's time, these three companies using Type A SATT Systems will have extended DDD service to nearly 300,000 subscribers on the West Coast.



Willard A. Rust began his career in telephony during his sophomore year at Northwestern University; as a "cooperative student" during his last three years of college, he alternated three-month periods at Automatic Electric and at NU's Technological Institute. Graduating in 1953, with a B.S.E.E., he entered the Testing Bureau of Automatic Electric Laboratories. In 1956, he was transferred to the Toll Ticketing group in the Telephone Switching section of Laboratories.

RELAYS for INDUSTRIAL APPLICATIONS

By E. S. Di Julio
Automatic Electric Laboratories, Inc.

Automation was still new in the '20's when Automatic Electric began to receive orders for relays, from engineers outside the telephone field. These engineers were designing circuits for industrial control —circuits based on those used in telephone switching — and they needed "telephone-type" relays to provide precise timing and margining values no other relays could give. . . . Today, our Industrial Products Division is serving engineers in hundreds of industries, ranging from machine tools to missiles. Besides the original "telephone-type" relays, Automatic Electric makes many novel types, to meet very unusual requirements. Some of these relays are described in this article.

Relays for High or Low Voltages

Since relatively few industrial controls operate at the 48 v., d.c., which is standard in the telephone field, various A.E. relays are made for operation in the range from 6 to 220 v., d.c.— and there are certain relays which operate directly on a.c. For the lower voltages, relays are simply made with coils especially selected to develop maximum power at the voltage available.

For higher voltages, however, additional insulation is provided around the coil core to reduce the danger of breakdown in this area, and if there is any danger of moisture-absorption additional protection is provided by varnish impregnation of the coil. Relays built in this way are often operated from 220 v., a.c., through a simple half-wave rectifier. But sometimes this construction is required also in relays operating at much lower nominal voltages; in one recent case, for example, AE engineers found that a number of relay coils connected in series in an industrial control circuit were being subjected to an inductive surge of about 4,000 volts when the circuit was opened!

Irrespective of the voltage at which they operate, industrial relays are often required to handle high voltages through their springs, necessitating additional insulation at this point. In some cases, insulation resistance is increased by lengthening

Figure 1. Class E Relay with 1/4" creepage paths over surface of spring insulation. Relay is 2 1/4" long.

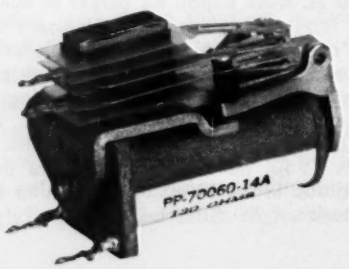
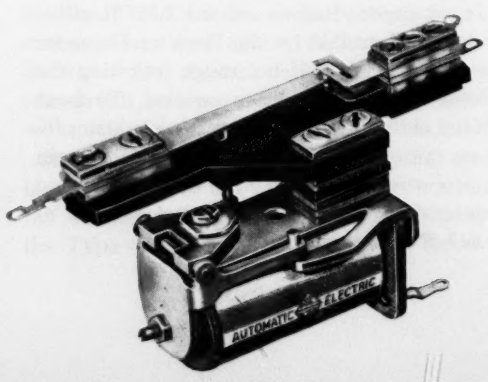


Figure 2. Class E Relay for video service has low capacitance between current-carrying parts, and to ground.



the creepage path over the surface of the insulation; a "one-quarter-inch creepage path" between adjacent springs is provided simply by adding an insulator that extends, on all sides, beyond the standard insulators. Or, pile-up insulators may be varnish impregnated for added breakdown resistance. While standard relays will withstand 500 v., a.c., these "Hi-Pot" (high-potential) relays will withstand test voltages of 1,250 v., a.c.

Relays to Handle Heavy Currents

When heavy current loads will be encountered in relay springs, special materials are provided that have high current-carrying capacity (together with the necessary flexibility) and resistance to heat. One of these materials is "Bronco" metal, a laminate of copper between two thicknesses of phosphor-bronze. Or one of a variety of beryllium-copper alloys may be used, to provide conductivity and good fatigue characteristics, even when heated by heavy currents. Special spring contacts of silver-cadmium oxide may also be employed, because they have the unique ability to quickly quench the arc that is formed when a heavy-current circuit is opened. And the standard spring buffers of mandrel-wound phenolic are often replaced by buffers of glass-filled Teflon, to withstand the heat.

Relays of Smaller Sizes

The requirements we have discussed so far can be met by relatively simple modifications of regular "telephone-type" relays. In many industrial applications, however, space is at such a premium that these relays cannot be used; AE engineers have solved this problem by developing smaller relays.

Figure 1, for example, shows a typical Automatic Electric Class E relay. Relays of this basic design will operate on 3.5 to 150 v., d.c., can handle up to 26 springs, and provide a wide range of pick-up and drop-out values (not all on one relay, of course). One version of the Class E relay operates directly on alternating current (up to 220 volts); another uses "snap-action" enclosed switches to handle currents as high as 10 amperes at 110 v., a.c. (noninductive load).

A modification of the Class E relay to provide low-loss control of video circuits is shown in Figure 2. To minimize capacitance effects at high frequencies, the contact springs are placed end-to-end, and are separated from the coil by a considerable distance; additionally, special low-loss insulation may be used, and shielding provided between the springs and the relay frame. Class E relays with these features have been found to have capacitance as follows:

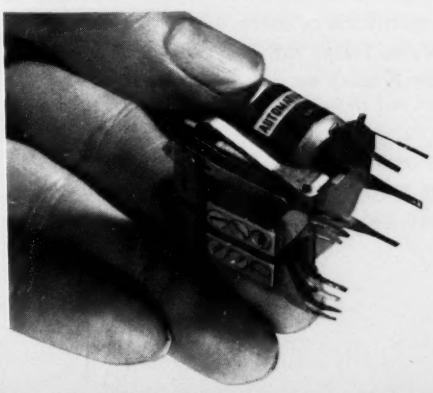
FREQUENCY	3 mc	10 mc	20 mc
Between springs	2.5 mmf	2.9 mmf	2.7 mmf
Between springs and ground	2.5 mmf	1.5 mmf	2.2 mmf

The smallest of all AE relays, however, is the Class S relay, shown in Figure 3. "Weighing in" at as little as two ounces, this type of relay can be supplied in assemblies with up to 18 contact springs, and coils for operation on up to 175 volts, d.c. Because of the small size of their coils, such relays cannot, of course, develop the sensitivity available with big "telephone-type" relays, but their size gives them definite advantages.

They are well adapted, for example, for mounting directly on printed-wiring boards. For this application, the coil and spring terminals are especially formed (Figure 4) to pass through

Figure 3. Two views of the Class S Relay, shown about actual size; weighs two ounces.

Figure 4. Class S Relay with coil and spring terminals formed for insertion into printed-wiring boards.



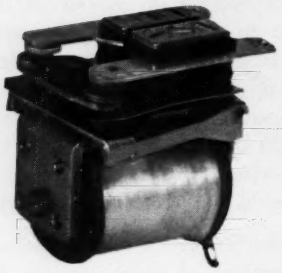


Figure 5. Class S Relay for switching heavy currents in small space; modified from basic structure.

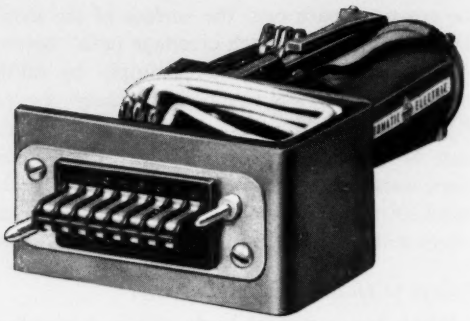


Figure 6. Telephone Type Relay with one of several available types of plug-in connectors.

mounting holes in the wiring board, the connections to be then completed by dip-soldering the entire board. Large quantities of these relays are used by leading manufacturers of computers, where their small size and dependable operation are invaluable. In such applications, these AE relays have a life of 100 million operations, plus!

The basic Class S relay structure has also been modified as shown in Figure 5, for use in power-handling operations which demand a small relay. Two, ¼" silver-tungsten contacts are mounted on a contact bar which is assembled to the modified armature by means of a bar spring. When the armature operates, the contact bar is free to "rock" on the spring. This type of action equalizes contact pressures as the two movable contacts engage the two stationary contacts, creating a series circuit through one 20-gauge phosphor-bronze stationary spring, one pair of contacts, the contact bar, another pair of contacts and the other stationary spring. This relay is rated for 25 amperes and 24 volts carrying capacity; however, tests which are now in progress indicate that it may be capable of carrying a resistive load of up to 60 amperes at 28 v., d. c., for as much as 50 000 operations or more, with a moderate duty cycle. Video relays are also available which use the Class S relay as a basic structure.

"Plug-in" Relays

When relays are used for vital circuits that should be out of service as little as possible—and especially when competent maintenance personnel may not be available—the relays are commonly assembled as "plug-in" units. Many different types of connectors are used on these units; a typical assembly is shown in Figure 6.

Another solution to this problem is the use of so-called "Taper-Tab" terminals, shown in Figure 7. As the name implies, these terminals are slightly tapered, so that a simple fitting on the end of each connecting wire may be pushed onto the proper terminal to complete a connection which is tight, yet may easily be opened. This type of connection is well adapted to use where relays may have to be changed occasionally, but not necessarily at high speed.

Protection from Environment

In many present-day applications of relays and switches, they are exposed to dust, high humidity, salt atmosphere, extremely low or high temperature, fungus growth, etc. Protection from all these environmental conditions can be secured, when practical, by hermetically sealing the unit within a metal can, with either solder-type or plug-in connections.

The relay which is to be sealed is completely wired to the terminals, inspected and tested, and then the enclosing can is placed over it, crimped and soldered in place. In the hermetic-sealing process, the complete assembly is pumped down, through an evacuation tube (Figure 8) to a few microns pressure. Then the can is flushed with

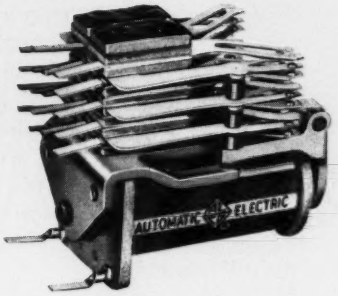


Figure 7. Class E Relay with "Taper-Tab" terminals, permitting quick connections, without soldering .

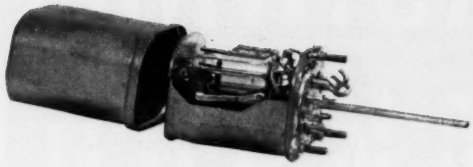


Figure 8. A typical hermetic-sealed, "ultraclean", High Current Relay, disassembled.

dry nitrogen, again pumped down, and filled with dry gas (usually nitrogen) to a pressure of at least one atmosphere, before the tube is pinched off and sealed.

Obviously, this involved hermetic-sealing process adds greatly to the cost of a relay, and for many purposes cannot be justified. In such cases, since the relay cannot be protected from a variety of environmental conditions, it must be built to withstand them!

Protection against humidity, for example, is provided by using relay coils that are completely impregnated with varnish, and relay pileups that are moisture-sealed by means of similar impregnation. For even more severe conditions (tropical climates or salt-spray atmospheres, or both), relays are safeguarded with fully impregnated coils and with fungicidal treatment to inhibit the growth of mold on parts (such as spoolheads) that are made of organic materials. This treatment is used, for example, on all relays for the U. S. Navy.

Relays for Aircraft and Missiles

So far, we have been talking about relays designed to overcome natural conditions, in reasonably normal surroundings. Today, however, relays are being used under conditions that are far from "normal". In aircraft, or in missiles, for example, a relay may be required to meet any of the following conditions (or even several of them at the same time):

CONDITION	RANGE
Temperature	−85°F to +300°F
Humidity	90-95 % RH at 40° to 160°F
Shock	35 G's
Vibration	10-20 G's at 5-1000 cps
Salt Spray	96 hours
Altitude	70,000 ft.
Insulation Resistance	1000 megohms, min.
Dielectric Strength	500 to 5000 V, RMS

The most pronounced effect of high temperatures (up to 300°F) is to thin out the lubricants used in the bearings of a relay. Extremely low temperatures, on the other hand, cause ordinary lubricants to solidify, so it is necessary to use synthetic plastic lubricants instead. The materials we use permit operation down to −40°F.

The humidity and salt-spray test requirements are met by use of special platings—such as chromium and cadmium—in addition to the provisions previously referred to. Of course, the housings of all hermetic-sealed relays are painted, for this same reason.

Shock and vibration requirements are met by counterbalancing the relay armature, or by mounting a heavy damper spring so it will bear down on the armature pin. The relay coil, normally mounted by only one screw at the heelpiece end, is also held by a coil anchor, which clamps the *armature* end of the coil to the heel-piece.

To meet the altitude requirement, it is necessary to prevent arc-over, which is more likely at

altitudes above 30,000 feet because of the tendency for ionization of the air at this low pressure. Relay pileups are arranged to provide long creepage distances over the surface of insulation, as previously described.

The requirements for insulation resistance and dielectric strength are satisfied by use of modern plastics, such as Teflon, Nylon, and Diallyl Phthalate, instead of the conventional insulating materials that meet ordinary requirements.

An "Ultraclean" Relay (Figure 8)

This relay is an excellent example of the extraordinary operating characteristics which are currently being demanded, necessitating special consideration of manufacturing techniques, and even of the surroundings in which the relays are made. The objective of this development was an ultra-reliable relay, capable of long storage life without any appreciable increase in contact resistance. Specifications called for closing a 112.5-ampere, 24 v., d.c., inductive load lasting 300 milliseconds, then dropping to 24 amperes for the remainder of a 20-second "on" period; this 24-ampere inductive load was then to be broken for a 20-second "off" period, and the cycle repeated. Furthermore, the relay was required to be hermetic-sealed in an enclosure measuring only 1-5/8" x 1-7/16" x 2-3/32".

Because of the size limitations, AE engineers selected the Class S relay as the basis of the new assembly. The specifications dictated a minimum of 100 grams contact-pressure, and a maximum operate current of 67 milliamperes; in addition, in order to prevent sustained arcs when opening the heavy load current, it was necessary to provide a minimum open-contact gap of 0.022". These requirements necessitated an exceptionally powerful coil to fit in the restricted available space.

The spring assemblies had to be especially designed to prevent their destruction from the heavy current load and the heat of the arc on circuit opening. To obtain instantaneous contact-opening on release, the contacts were placed at the end of the springs, for greatest movement. Springs of beryllium-copper 10 were used to prevent annealing of the springs, and high-temperature glass-filled Teflon buffers were selected. Palladium contacts, 0.125" in diameter, were provided to carry the heavy contact load.

Since the relay was to be hermetic-sealed, it was necessary to guard against "outgassing" of materials (and consequent contact contamination) at the high temperatures that would be developed. Organic materials had to be replaced by inorganic, wherever practical—organic materials being used only if they exhibited low outgassing characteristics. Pileup insulators of Alsimag (96% Al_2O_3 with MgO and SiO_2) were therefore used, and Teflon-coated wire and bobbins were provided in the coil assembly.

Finally, to assure that the relay would be "ultraclean" when sealed into its housing, many special precautions had to be observed. A dust-free environment was provided, and ultrasonic cleaning was employed at many steps in the assembly.

To the untrained eye, this new ultraclean relay may look very little like a "telephone-type" relay. The engineers who specify it in great numbers for use in their products know, however, that its design owes much to AE's nearly seventy years' experience in this field.

Ernest S. Di Julio received his BSME from Illinois Institute of Technology in 1952. He joined Automatic Electric in May, 1954, and gained varied experience in Quality Control, Production Engineering, and the Testing Bureau of Laboratories. In 1955, he was transferred to the Electromechanical Design section, and in 1958, he became a Group Leader; his group has primary responsibility for the development of industrial relays, switches, and allied products. Mr. Di Julio is a member of Tau Beta Phi and Phi Tau Sigma.